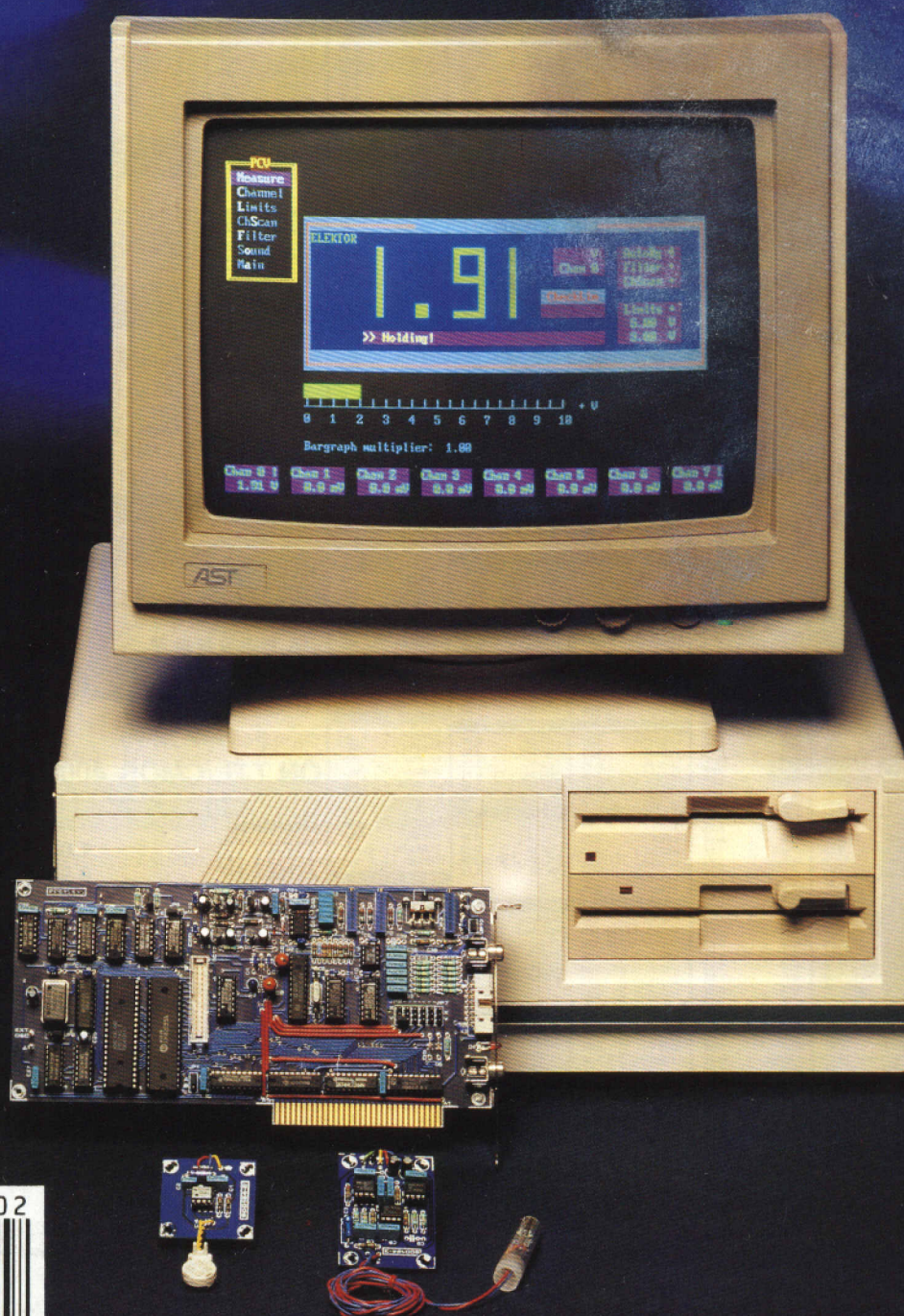


**Elektor  
Electronics**

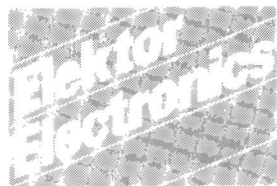
**RDS decoder**  
**Simple function generator**  
**MIDI-to-CV interface**  
**Decadic voltage dividers**  
**Serial video card**  
**Central heating controller**



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02





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February 1991  
Volume 17  
Number 186

## In our next issue:

- Headphone amplifier
- Electronic exposure timer
- 6.0 MHz TV sound demodulator
- PC-controlled semiconductor tester
- Radar detector
- 2 m converter
- Multi-channel audio/video switch

## Front cover

The picture shows the voltmeter function, PCV, of the Multifunction Measurement Card for PCs in action. The two basic measurement functions offered by the card, a voltmeter and a frequency/pulse meter, are frequently required in the electronic workshop or laboratory, but not commonly implemented on a PC. At least, not at the accuracy achieved by this card: the voltmeter and the frequency meter have the remarkable precision of 12 bits and 6 digits respectively, which is up to par with the specs of much more expensive (industrial) products. On the EGA monitor you can see the colourful PCV menu, which offers a host of features for multi-channel multiplexed measurements, auto-calibration and range settings. The large voltmeter indication will be familiar to readers who have already digested Part 1 of the relevant article (don't worry if you don't get the meaning of 1.91).

In forthcoming issues, we intend to publish a number of practical applications of the system.

Copyright © 1991 Elektor BV

**ABC**

MEMBER OF THE AUDIT  
BUREAU OF CIRCULATIONS

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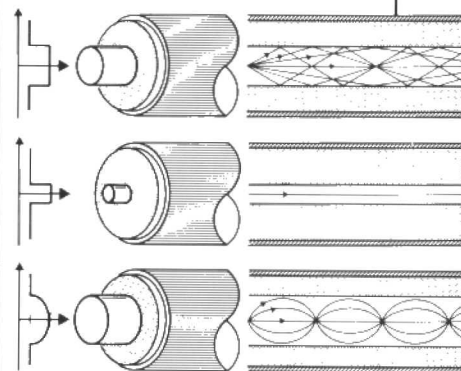
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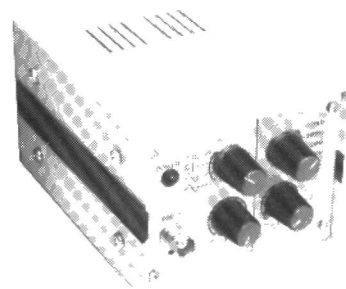
Electronics scene **11, 12**; Events **12**; New books **13**; Readers services **63**; Index of advertisers **74**.

## APOLOGIES

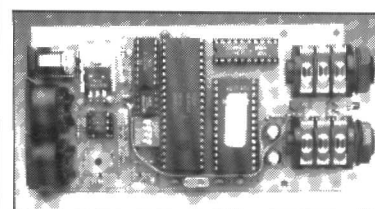
We regret that, owing to circumstances beyond our control, it was not possible to include the following in this issue: The complete preamplifier Part 2 : 6.0 MHz TV sound demodulator; PC-controlled semiconductor tester.



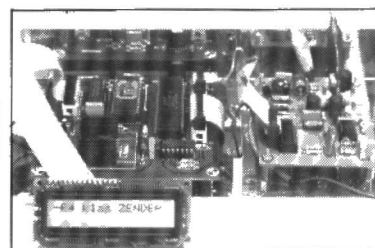
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p. 34



Simple function generator - p. 42



MIDI-to-CV interface - p. 53



Radio data system (RDS) decoder  
p. 56



## COMPUTER SYSTEM WILL HANDLE 36 LANGUAGES

A NEW £3.2 million British computer system, to be introduced later this year, will handle the texts of all BBC World Service broadcasts—in 36 languages.

When fully operational, the 930-screen system developed by Basys International will link all newsroom and program-making departments both in London and elsewhere in the UK. Full advantage will be taken of state-of-the-art optical-fibre technology to link parts of the system.

World service currently broadcasts 785 hours of programmes every week and its round-the-clock newsroom produces more than 200 programmes daily.

BBC International, PO Box 76, Bush House, Strand, London WC2B 4PH.

## GERMANY WILL USE BRITISH PAYPHONES

GERMANY is to use British equipment for its new nationwide system of payphones operated by credit card. A field trial has already been carried out at Frankfurt, Düsseldorf, Munich and Hamburg airports and as a result of its success, Deutsche Bundespost Telekom—DBP—will now extend the service throughout Germany using credit card payphones and other equipment supplied by GEC Plessey Telecommunications (GPT). The GPT phones will accept all major credit cards.

GEC Plessey Telecommunications Ltd, PO Box 53, Coventry CV3 1HJ.

## NEW SPONSORSHIP DEAL AND PROGRAMME FOR YEDA

THE trustees of the Young Electronic Designer Awards (YEDA) have announced that Mercury Communications have become joint sponsors of YEDA. Texas Instruments have sponsored the scheme for the past five years and had guaranteed YEDA's survival into 1991. The new joint sponsorship ar-

## ELECTRONICS SCENE



Nicholas Mason demonstrating his electronic musical instrument for the disabled to Lucy Moore of Mercury Communications. Nicholas, a prize winner in the 1989 Young Electronic Designer Awards, is a former pupil of Sanden School, Chelmsford, and is going to Surrey University later this year.

rangements provide long-term security for YEDA.

Following the regional judging now taking place, the finals of YEDA 1991 will be on Wednesday, April 3, at the Science Museum in South Kensington, London.

The YEDA Trust, 24 London Road, Horsham, West Sussex RH12 1AY.

## INMARSAT-2 SATELLITE UP ... AND RUNNING

IMMARSAT-2, the new commercial global mobile communications satellite, launched from Cape Canaveral, Florida, last October, is in geostationary orbit. Early operations on the satellite have gone so well that command of the spacecraft was handed over from the Centre National d'Etudes Spatiales (CNES)

to Inmarsat's satellite controllers ahead of schedule. The French agency in Toulouse performed the initial manoeuvres and checks on the satellite.

Inmarsat, 40 Melton Street, London NW1 2EQ.

## BRITISH AND RUSSIAN CHILDREN COMMUNICATE BY COMPUTER

DIRECT computer links have been established between schoolchildren in Britain and Russia. The first link is between the Moorside High School at Werrington, Stoke-on-Trent, and a school in Moscow, and is now being used by pupils to discuss world environmental problems.

The aim is to set up a forum so that computer equipment suitable for educational use can be exchanged and marketed in each country. In doing so, it is hoped a mechanism will be created to allow students and teachers in the UK and Russia to communicate not only in both languages, but on a variety of subjects.

## EASIER RADAR TESTING WITH TRANSPORTABLE SYSTEM

COMPLEX radar signals can now be tested by a transportable system from Racal Instruments. Described as the world's first microwave radar test system, it simplifies the analysis of radar signals that until now has needed a large and expensive automatic test equipment (ATE) system.

Housed in a high-performance low-noise and fully screened VXI chassis, the system is built around a new instrument known as a VXI Time Interval Analyser. The analyser allows a combination of high-resolution continuous measurements with simultaneous data collection. It can measure pulse width, pulse repetition frequency (PRF) and rise and fall time in addition to identifying spurious signals. It can also identify signatures and parameters of coded radar waveforms.

Racal Instruments Ltd, 480 Bath Road, Slough, Berkshire SL1 6BE.

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## ANGLO-GERMAN MERGER WILL CREATE US GIANT

**A** PLAN to merge Stromberg-Carlson Corporation, a member of the GEC Plessey Telecommunications Group, and Siemens Communication Systems in the USA will create North America's third biggest public network supplier of telecommunication equipment.

The new company will operate as Siemens Stromberg-Carlson and involve 4,000 workers located in manufacturing sites in Florida, Arizona and New Mexico. Together, they will design, develop, produce and market computerized public telephone switches, packet switching and transmission systems.

GEC Plessey Telecommunications Ltd, PO Box 53, Coventry CV3 1HJ.

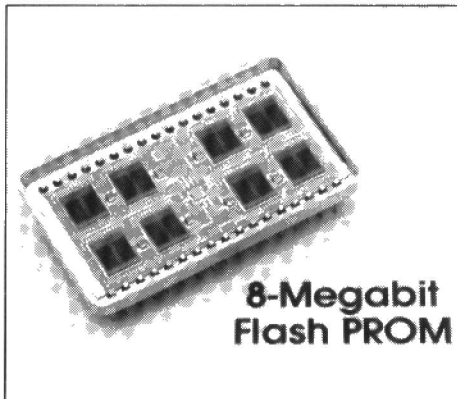
## SMART ANTENNAS PROMISE IMPROVED COMMUNICATIONS

**S**MART antennas that can sense and adapt automatically to their electromagnetic environment have evolved rapidly in recent years primarily because of advances in digital signal processing technology.

This type of antenna will play a vital role in a wide range of future communications systems caused by the growing need for improved performance in an increasingly congested electromagnetic environment and the pressure for low-cost solutions in a sophisticated consumer market. To assist organizations involved in the development and provision of communication services to determine the potential of smart antennas, ERA Technology is launching a programme of applied research and technology transfer directed at the exploitation of smart antenna technology for future communications.

ERA Technology Ltd, Cleeve Road, Leatherhead, Surrey KT22 7SA.

## ELECTRONICS SCENE



**8-Megabit  
Flash PROM**

## 8-MEGABIT FLASH EPROM FROM WHITE

**W**HITE Technology's new WF-1024K8-150 hybrid is an 8-megabit flash EPROM module in a 34-pin sealed metal package that is believed to be the smallest available holding that much memory. The device is built with eight 1 Mbit CMOS flash memories assembled on a thick-film substrate. This provides a non-volatile storage of 1 Mbyte×8.

Details from White Technology Inc., 4246 E. Wood Street, Phoenix, Arizona 85040.

## 10-PATENT MAN IS INVENTOR OF THE YEAR

**S**TEPHEN Ferguson, an advanced-systems manager with GEC Plessey Telecommunications (GPT), has been named Inventor of the Year (1990).

The annual award, given by GPT, recognizes Mr. Ferguson as one of the leading exponents of the Synchronous Digital Hierarchy

(SDH). This is a sophisticated method of combining telecommunications traffic for transmission in a network in such a way that it can be rerouted and portions may be repackaged with greater flexibility. This has the advantage of giving network operators better use of their resources and provides a flexible infrastructure for new services.

The Inventor of the Year award is aimed at stimulating awareness of intellectual property and encouraging engineers to protect their patents. Judging is based on innovative merit and potential value of patents during the award year.

Among the early achievements of Mr Ferguson after joining GEC Telecommunications as a graduate trainee in 1967 was the development of noise reduction methods that improved the quality of communication over high-capacity links. Over the years, Mr Ferguson's work has led to the registration of 10 patents.

GEC Plessey Telecommunications, PO Box 53, Coventry CV3 1HJ.

## ELECTROCOMPONENTS PLC

**I**N spite of depressed market conditions and exports being adversely affected by the Gulf crisis, Electrocomponents PLC, owners of, among others, RS Components, Misco, Verospeed and Mesa, have experienced continued growth over the 12 months to September last. Operating in most of Europe, North America and Australia, with a sales turnover of close to £400 million, the group claims to be the largest electronic component retailer and mail order business in Europe. Through Verospeed, it has operations in France and Austria, while RS Components is about to commence operations in Frankfurt.

Electrocomponents PLC, 21 Knightsbridge, London SW1X 7LY.

## IEE AND IEEE PROGRAMME

- 1 February—Expert systems and safety.
- 4 February—Civil applications of sonar systems.
- 5-7 February—62nd Faraday Lecture.
- 6 February—Processing for security.
- 7 February—Multimedia communications and applications.
- 7 February—Enhanced and widescreen PAL.
- 8 February—The teaching of software engineering.
- 12 February—Neural networks: design techniques and tools.
- 13 February—New developments in pulsed power technology.
- 14 February—8th Computing and Control Lecture.
- 15 February—Recent advances in broadcast TV cameras
- 18 February—Analogue to digital converters.
- 18 February—Planning for integrated services digital networks.
- 20 February—Professionalism in engineering design: European perspectives.

## EVENTS

- 22 February—Replacement of old and unreliable cables.
  - 27 February—Investing with confidence in robotics.
  - 27 February—Future mobile radio trunking and data systems.
  - 27 February—Image communication in the car of the future.
  - 28 February—The significance of accuracy of calibration in industry.
- Information on these, and many other, events may be obtained from the IEE, Savoy Place, London WC2R 0BL, or the IEEE, Savoy Hill House, Savoy Hill, London WC2R 0BS.

The following exhibitions have been organized by Blenheim.

- 6-8 February—Mapping awareness (computer systems) at the Olympia Exhibition

Centre, London.

- 12-15 February—PC forum at the Porte de Versailles, Paris.

- 12-15 February—Telecom network '90 at the Porte de Versailles, Paris.

The date and venue of the Microtex exhibition have yet to be confirmed.

Full details may be obtained from Blenheim Exhibitions Group, Blenheim House, 137 Blenheim Crescent, London W11 2EQ, telephone 071 727 1929.

Two important events in the ERA Technology calendar are:

- 13-14 February—6th annual conference and exhibition on electromagnetic compatibility (EMC) at the Heathrow Penta Hotel.

- 26-27 February—Electrical power utilization: how to achieve system performance. This conference and associated exhibition will take place at the Heathrow Penta Hotel.

Details from ERA Technology, Cleeve Road, Leatherhead, Surrey KT22 7SA.



**ENCYCLOPEDIA OF ELECTRONICS**

Second edition

Edited by Stan Gibilisco and Neil Sclater

ISBN 0 830 633 898

960 pages - 285×225 mm

Price £65.95 (hard cover)

This is a 'big' book in every sense of the word and it remains the best single-source reference available for anyone interested in electronics. This new edition has been revised extensively to take account of the fast pace at which electronics is proceeding. New entries include artificial intelligence; surface-mount technology; compact discs; fax machines; high-definition TV; communication satellites; superconductivity; local area networks; and many more.

The work is not confined to electronics, but also includes concepts in physics, mathematics, computer science, chemistry, and other subjects that relate to electronics.

Subjects are arranged alphabetically and accurately cross-referenced and indexed, which makes finding what you're looking for very easy indeed.

The book's reputation rests on that of the co-editors. Stan Gibilisco is the author or co-author of several other distinguished reference works, including the *Illustrated Dictionary of Electronics* (reviewed in the October 1988 issue of *Elektronika*) and the *International Encyclopedia of Integrated Circuits*.

Neil Sclater, an electronics engineering consultant, has written dozens of feature articles for such publications as *Communications News*, *Control Engineering*, *Design Engineering*, and many others. He is the author of two other books, *Electrostatic Discharge Protection for Electronics*, and *Gallium Arsenide IC Technology*.

We cannot but recommend the new *Encyclopedia of Electronics* to every electronics enthusiast: this important work should be available in all colleges, polytechnics, universities and general libraries.

McGraw-Hill Book Company, Shoppenhangers Road, Maidenhead, Berkshire SL6 2QL.

**PRACTICAL MIDI HANDBOOK**

Second edition

by R.A. Penfold

ISBN 1 870775 13 9

160 pages - 216×138 mm

Price £6.95 (soft cover)

This new edition of the *Practical MIDI Handbook* is, like its predecessor (reviewed in the September 1988 issue of *Elektronika*), aimed primarily at musicians, enthusiasts and technicians who want to exploit the vast capabilities of MIDI, but who have no previous knowledge of electronics or computing.

The larger part of the book is devoted to an explanation of what MIDI can do and how to exploit it to the full, with practical advice on connecting up a MIDI system and getting it to work, as well as deciphering the technical information in those equipment manuals.

The second edition has been updated to include information on standard MIDI files and to cover recent developments in sequencers

**NEW BOOKS**

as well as the multimode and other features recently implemented by some synthesizer manufacturers.

PC Publishing, 4 Brook Street, Tonbridge, Kent TN9 2PJ.

**PRINCIPLES OF TRANSISTOR CIRCUITS**

Seventh edition

by S.W. Amos

ISBN 0 408 04851 4

351 pages - 215×130 mm

Price £16.50 (soft cover)

Although the use of integrated circuit circuits has become all encompassing since the previous edition of this book, there is still a role for discrete transistors, particularly where appreciable power output or high-voltage operation is required. Discrete transistors are also likely to be used in experimental work and in the early stages of design of an electronic equipment.

Like its predecessors, this book deals in detail with the design of amplifiers, receivers and digital circuits that use discrete components, but the text has been updated throughout. Some dated material has been removed, while a number of old circuits diagrams have been replaced by modern ones.

A number of useful appendices provide information on transistor manufacture and parameters.

The work should be of great interest to the student of electronic/electrical engineering (it has already been adopted as a standard course book by many technical colleges) and to the serious enthusiast. Butterworth-Heinemann, Westbury House, Bury Street, Guildford GU2 5BH.

**HIGH-FREQUENCY SWITCHING POWER SUPPLIES - Second edition**

by George C. Chryssis

ISBN 0 07 010951 6

287 pages - 235×155 mm

Price £39.95 (hard cover)

Virtually every section of the new edition of this important book has been revised and expanded to obviate any guesswork in the engineer's analysis and design of modern switching power supplies. There is a mass of working information and ready-to-use diagrams for designing effectively in all phases—from input to output, transformer design, control ICs and switching elements.

Formulas and related information cover a vast area, including advances in magnetic amplifiers, new topologies for operation over 100 kHz, resonant converters, synchronous rectifiers, bipolar transistors and MOSFETs, PWM control ICs, output supervisory circuits, feedback loop stability analysis, the EMI-RFI problem and power safety standards.

McGraw-Hill Book Company, Shoppenhangers Road, Maidenhead, Berkshire SL6 2QL.

**A CONCISE INTRODUCTION TO EXCEL**

by N. Kantaris

100 pages, soft cover, illustrated

ISBN 0 85934 224 7

Price: £3.95

Excel is Microsoft's renowned product in the field of PC spreadsheet production. A spreadsheet is today's businessman's way of presenting data on cost, production, turnover, etc. with the aid of tables and charts. With the size of today's electronics market in mind, an increasing number of employees in the industry will require some understanding of commercial aspects, whence the need to be familiar with the basics of spreadsheets.

This book, though rightly called an introduction, covers all aspects of spreadsheet production using Excel, from data entry, sorting and database management to printing sophisticated pie and bar charts that bring otherwise boring numbers alive. The book covers Excel versions 2.0 and 2.01(C), running as a single application, or under Windows version 2.0, 386 or 3.0. The screendumps in the book, the many examples, and the clear didactic structure of the chapters cover all the main features of Excel.

**AN INTRODUCTION TO AMATEUR SATELLITE COMMUNICATIONS SATELLITES**

by A. Pickard

102 pages, soft cover, illustrated

ISBN 0 85934 235 2

Price: £3.95

Few people seem to be aware of the fact that radio amateurs have played an important role in the history of satellite communications. In this day and age of satellite TV and transatlantic telephone conferencing, communication via a non-geostationary satellite designed, operated and 'flown' by the joint effort of scientists and radio amateurs is still a fascinating hobby.

Mr. Pickard's book has all the background information on low-orbiting communications satellites that can be received with fairly simple means, concentrating mostly on the UoSat, NOAA and MeteoSat (which is geostationary), which transmit in the 137 and 1690 MHz bands. Equipment is outlined, and a good introduction presented on the way satellites can be tracked during the 'low' part of their orbit.

**Bernard Babani (publishing) Ltd.**  
The Grampians, Shepherds Bush Road,  
LONDON W6 7NF



# MULTIFUNCTION MEASUREMENT CARD FOR PCs

## PART 2: CONSTRUCTION, ADJUSTMENT SOFTWARE AND PRACTICAL USE

Following last month's formal description of the operation of the measurement card, many of you will be keen on tackling the more practical side of things. In this second and final instalment we concentrate mostly on the construction, which is fairly easy, and on the powerful, menu-driven control software package that brings the card alive on your PC.

J. Ruffell

### Reorienting

Having digested all the information on the design and operation of the measurement card presented in last month's instalment, we can now start to look at the construction of the unit. As shown in the photograph of our prototype, the printed-circuit board is fitted with a support bracket of the type used in PCs to secure insertion cards to a frame at the rear side of the computer. The PCB accommodates four connectors used for the various types of measurement. The upper two connectors, K1 and K3, are for the analogue measurements, while the lower one, K2, forms the protected digital input for frequency and pulse measurements. The other digital inputs are provided on connector K6, which is located next to the two PPis (8255s) on the left-hand part of the PCB. Between connectors K2 and K3 we find LED D4, an indicator which lights during the gate time when measurements are carried out on digital signals.

The lower edge of the PCB has the familiar PC extension bus connector, which consists of gold-plated contact fingers. To the top, at the right, we find the three multiterminal presets, P1, P2 and P3, and switch S1. As will be detailed later, these components play an important role in the adjustment of the card. During the adjustment, the switch is used to generate two calibration signals. The two PCB solder pins to the right of P3 (marked 'adj.') form an adjust output, which is used during the alignment of the ADC only.

### Building the card

The track layouts and the component mounting plan of the printed-circuit board are given in Fig. 3. As a matter of course, this PCB is double-sided and through-plated. Having noted that the PC bus extension con-

### COMPONENTS LIST

#### Resistors:

1	10 $\Omega$	R1 (see text)
2	13k $\Omega$ 1%	R2;R4
2	6k $\Omega$ 19 1%	R3;R5
*	see text	R6-R19
2	22k $\Omega$	R20;R34
1	24k $\Omega$ 3 1%	R21
1	1k $\Omega$ 20 1%	R22
1	280 $\Omega$ 1%	R23
1	953 $\Omega$ 1%	R24
1	3k $\Omega$ 209 1%	R25
5	10k $\Omega$ 1%	R26;R39-R42
1	32k $\Omega$ 4 1%	R27
1	110k $\Omega$ 1%	R28
1	453k $\Omega$ 1%	R29
1	22M $\Omega$	R30
1	523k $\Omega$ 1%	R31
1	487k $\Omega$ 1%	R32
1	10k $\Omega$	R33
3	330 $\Omega$	R35;R37;R38
1	100 $\Omega$	R36
1	2M $\Omega$	R43
1	820 $\Omega$	R44
3	500 $\Omega$ multiterm preset	P1;P2;P3

#### Capacitors:

5	100nF ceramic	C1;C4;C7;C9;C10
2	47 $\mu$ F 25V tantalum	C2;C8
1	10 $\mu$ F 25V tantalum	C3
2	56pF	C5;C6
7	22nF ceramic	C13;C14; C19-C22;C40
2	470nF 63V MKT	C11;C12
8	47 $\mu$ F 16V radial	C15-C18; C23-C26
7	100nF	C27-C32;C42
7	optional; see text	C33-C39
1	470nF	C41
1	1nF	C43
3	100nF ceramic SMD	C44-C46
1	10 $\mu$ F 25V tantalum	C47

#### Semiconductors:

3	BAT85 (PC)	D1;D5;D6
2	1N4148	D2;D3

1	LED red 3 mm	D4
2	TL431CLP (TI)	D7;D8
1	BC557B	T1
1	74HCT245	IC1
1	74HCT240	IC2
1	74HCT244	IC3
1	AD7572AJN03 (AD)	IC4
1	74HCT08	IC5
3	74HCT74	IC6;IC19;IC20
1	PAL 16L8 (ESS561)	IC7
1	74HCT02	IC8
1	OP200 (PMI)	IC9
2	74HCT4051	IC10;IC12
1	TLC2652 (TI)	IC11
2	82C55 (I;UMC)	IC13;IC14
1	74HCT86	IC15
1	74LS292	IC16
1	79L08	IC17
1	74HCT153	IC18
1	LS7060 (LSI)	IC21
1	74HCT151	IC22
1	78L08	IC23

#### Miscellaneous:

1	10-MHz oscillator block	OSC1
2	PCB-mount phono socket	K1;K2
1	16-way box header with angled pins	K3
1	26-way box header	K6
1	SPDT slide switch	S1
1	4 MHz quartz crystal	X1
1	PC card support bracket BICC-Vero type G99.	
1	printed circuit board	900124

#### Manufacturer codes:

TI = Texas Instruments  
 PMI = Precision Monolithics Inc.  
 PC = Philips Components  
 I = Intel  
 UMC = United MicroElectronics Corp.  
 LSI = LSI Computer Systems Inc.  
 AD = Analogue Devices



nector is gold-plated for optimum contact with the slot connector in the PC, you will agree that is hard, if not impossible, to produce this PCB yourself and match the quality of the one supplied ready-made.

It is recommended to use thin solder tin, and a low-power solder bit with a very fine tip. Those of you confident of their soldering skills may want to do without IC sockets in the analogue section of the circuit (the analogue section essentially consists of the ADC, the two multiplexers and the three associated opamps). In practice, it is often found that soldered connections are better than (inexpensive) IC sockets, which tend to develop bad contacts. If you are hesitant about soldering the (fairly expensive) components in the analogue section, consider the use of IC sockets with turned pins.

Overall, the construction of the card is simple and straightforward if you follow the parts list and the component overlay printed in white on the PCB. One area that deserves special attention, though, is the decoupling of the ADC chip. To enable the ADC to achieve the specified accuracy, it requires decoupling capacitors that are fitted as close as possible to the IC. If the decoupling is inadequate, a number of the lower significant bits are not stable, making the measurements unreliable. From the PCB layout it is seen that the ADC chip is fitted with three surface-mount assembly (SMA) decoupling capacitors, C44, C45 and C46, which can be mounted very close to the IC because they have no leads. It should be noted that C44 is mounted only when the -A type ADC is used. A further decoupling capacitor, C47, is a tantalum bead type mounted at the solder side (i.e., the non-component side) of the board.

The special decoupling of the ADC, together with the filter function of the software, ensures that the measurement results are degraded only by the  $\pm 1$ -bit error of the LSB (least-significant bit). As discussed last month, this error occurs in all analogue-to-digital conversion processes, and can not be eliminated.

The final accuracy of the frequency measurement is basically achieved by the software, which has a filter function that builds the actual measurement value from up to a thousand measurement results obtained from very fast sampling. By evaluating all these measurement results, the software is capable of eliminating errors caused by, say, a small spike, or random interference.

Jumpers JP2 to JP8 need not be fitted as yet, because the software will also function without hardware interrupts implemented. As detailed last month, jumper JP1 sets the base address of the card. Install it as required, with reference to Table 1.

Jumper JP9 must be set to position C when the on-board 10-MHz oscillator is used. Position D is used when an external reference oscillator is connected. The function and use of jumper JP10 is discussed later in connection with the adjustment of the ADC.

Depending on the desired measurement

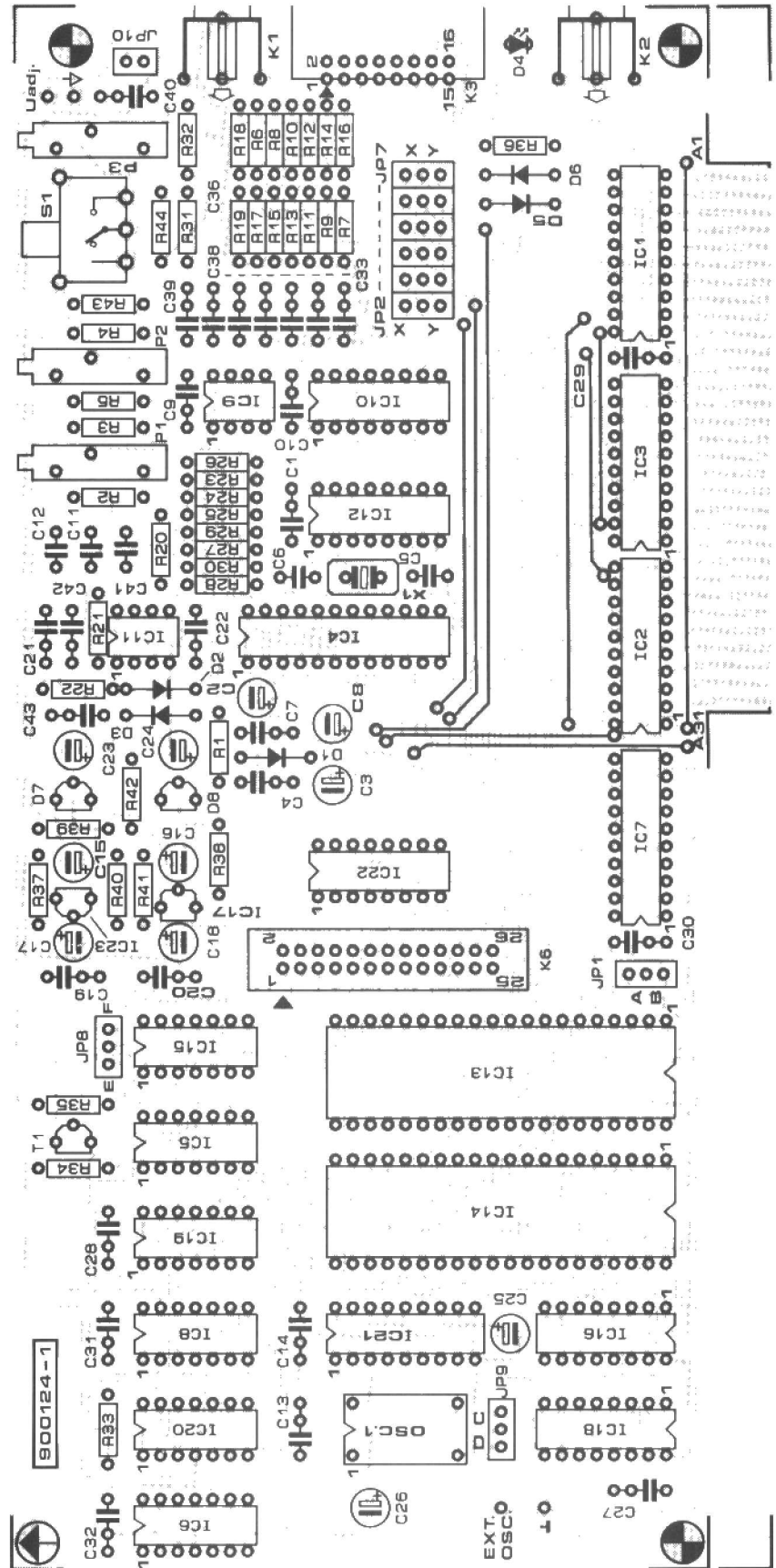


Fig. 3a. Component overlay of the double-sided, through-plated printed circuit board.



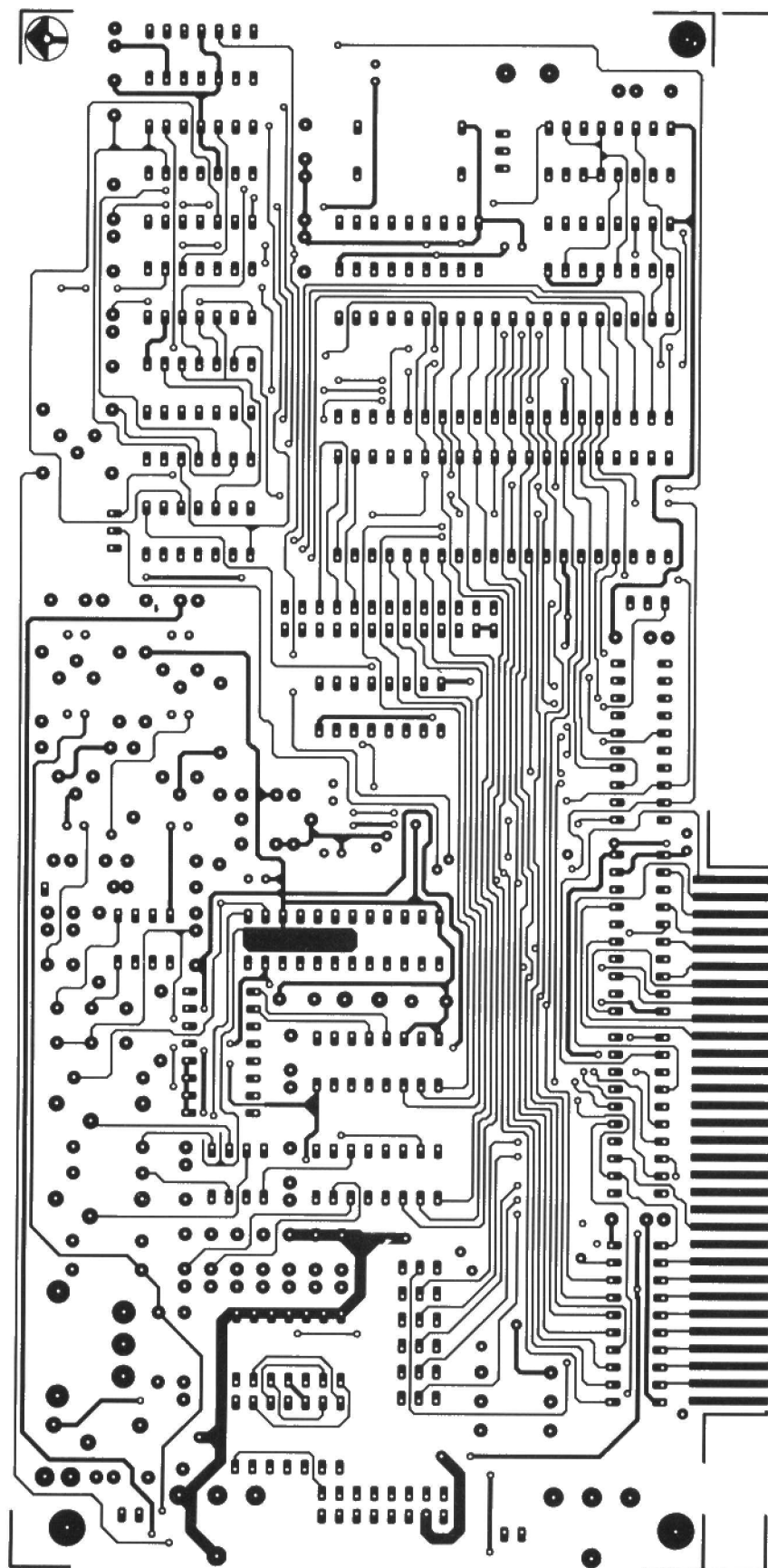


Fig. 3b. Track layout (mirror image) of the component side of the board.

## SOFTWARE SERVICE

This project is supported by two items in the Elektor Software Service (ESS) range:

- a diskette, order number 1461, containing the control program (MS-DOS format, 5¼-inch, 360 k);
- a ready-programmed PAL type 16L8 (IC7), order number 561.

For prices and details on ordering these products, please refer to the Readers Services page elsewhere in this issue.

range on multiplex channels 11 to 17, you must dimension resistors  $R_6$  to  $R_{19}$  yourself. To prevent measurement errors caused by large ground currents, these resistors preferably take high values. For the same reason, do not load the +8 V reference voltage on connector K3. As indicated in the circuit diagram, the junction of each potential divider may be decoupled for alternating voltages with the aid of a capacitor ( $C_{33}$  to  $C_{39}$ ).

## Software

In all fairness, a piece of high-tech electronics like the PC measurement card is of little use when you have no software to control it properly. Fortunately, such software exists, and is available in a ready-to-go state on a diskette for all PC-XT/AT MS-DOS computers.

The control program developed for the measurement card has been written in Turbo Pascal, and uses a large number of coloured menus to show the various measurement results. The software is uncritical as regards the type of PC, and can be used with video adapters such as the Hercules, EGA and VGA (not with the CGA). The software for the prototype card was written and successfully tested on a PC-AT with a hard disk, 640 kB of memory, MS-DOS version 3.2, and an EGA video card. A hard disk is not strictly required for the software to be used, but it does offer the additional comfort of faster switching between parts of the program.

If you have a hard disk, create a subdirectory for the measurement card, and copy all the files from the distribution floppy disk into this subdirectory. If you do not have a hard disk, make a working copy of the distribution disk, and store the latter safely for use as a back-up. Make sure that the working copy is not write-protected.

The diskette supplied for the project has two .EXE files: PCV.EXE, which starts the voltmeter program, and PCF.EXE, which starts the program for time-related measurements. Also on the disk are a number of configuration files used by the two programs.

Before using PCV.EXE or PCF.EXE, make sure that the configuration contained in ADCF.CFG is correct. If you inspect this file, you will find that the defaults are:

- base address: \$0300
- reference frequency: 10 MHz,  
on-board XTO
- maximum gate time: 410 s
- full-scale voltage: 2.5 V

In most cases, the default settings allow PCF and PCV to be used straight away, unless you require a change in the base address. If necessary, edit the ADCF.CFG configuration file with the aid of a (simple) word processor such as EDLIN, PCTools, Norton or Side-Kick.

## PCV, the PC-controlled Voltmeter

After fitting the card in the PC, leave the cover open as yet to provide access to the three multirun presets. Run PCV, and check that the main menu appears (see Fig. 4). If the program reports that the card is not found, you have a problem. Not to worry, though: check for the correct base address in software (the configuration file) and in hardware (jumper JP1). If this is all right, a section of the hardware may not function properly, or the card causes an address conflict in the PC. Investigate and rectify the problem before proceeding.

Once you are looking at the main menu, you may confidently embark on the adjustment of the card. The adjustment procedure effectively matches the software to the hardware, ruling out the effect of component tolerances on the measurement results.

### Adjust

Start by selecting the 'Adjust' option from the main menu. The information presented by this option, shown in Fig. 5, is clear and allows the ADC on the card to be calibrated quickly and efficiently. As already mentioned in part 1 of this article, channel I1 is used for the calibration of the ADC. Therefore, do not forget to disconnect R19, and fit R18 (or, if applicable, a wire link) on the PCB. The program then performs the adjust routine and provides all the instructions and help you need to achieve satisfactory results.

### Learn

On completion of the 'Adjust' routine, return to the main menu. From there, select the 'Learn' option to calibrate the attenuators on the eight analogue inputs. The 'Learn' routine allows you to tell the program which attenuation is applicable at the inputs of the various analogue channels. The software automatically eliminates the tolerances in the ladder attenuators, and offers a number of options that allow you to select the analogue channel of which the transfer function (i.e., the attenuation) is to be 'learned'. As long as inputs I1 to I7 are not connected to additional attenuators, their maximum input voltage range is  $\pm 2.5$  V at a conversion factor of 1. Nonetheless, these inputs need to be calibrated to enable the program to be initialised.

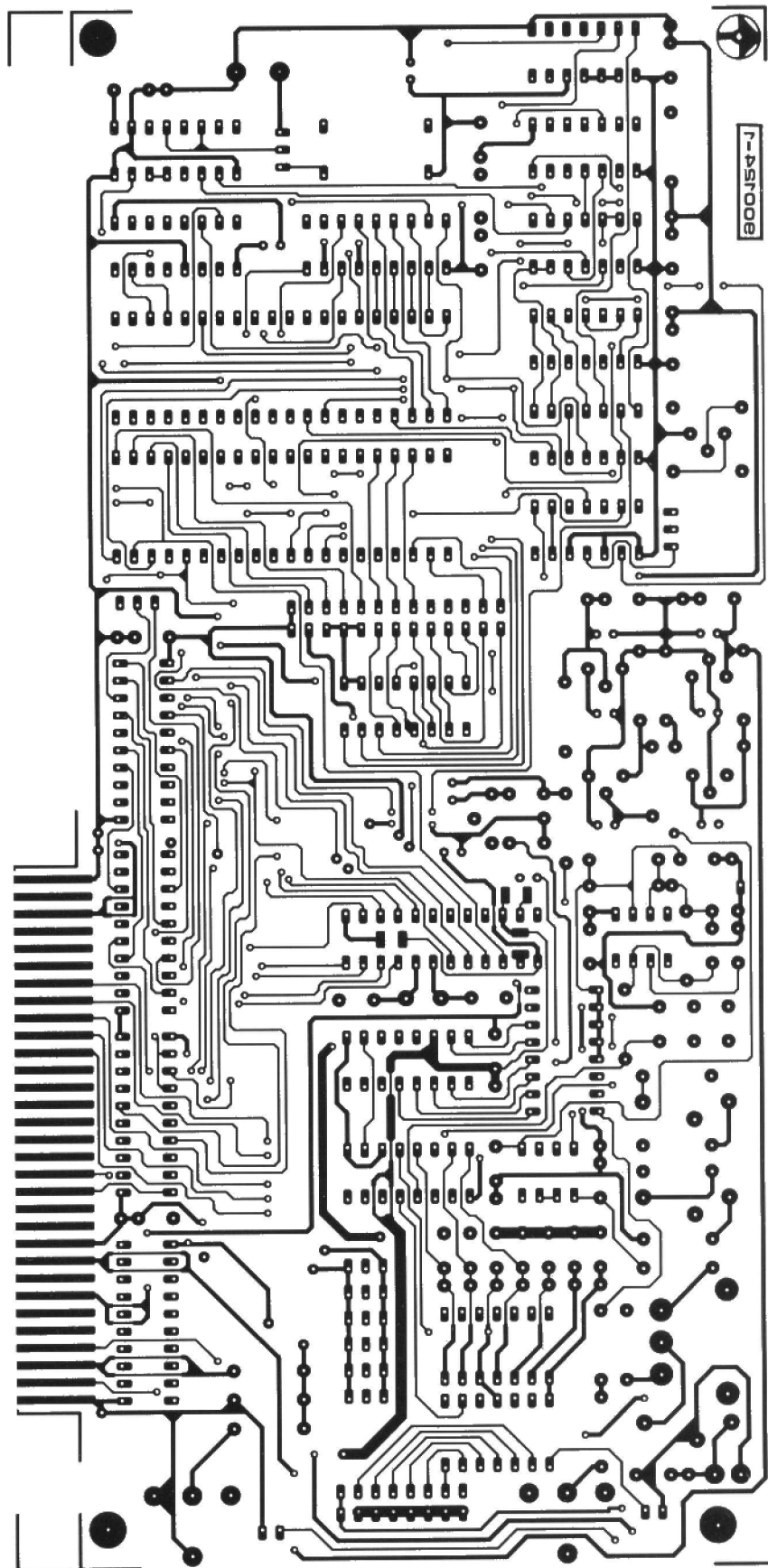
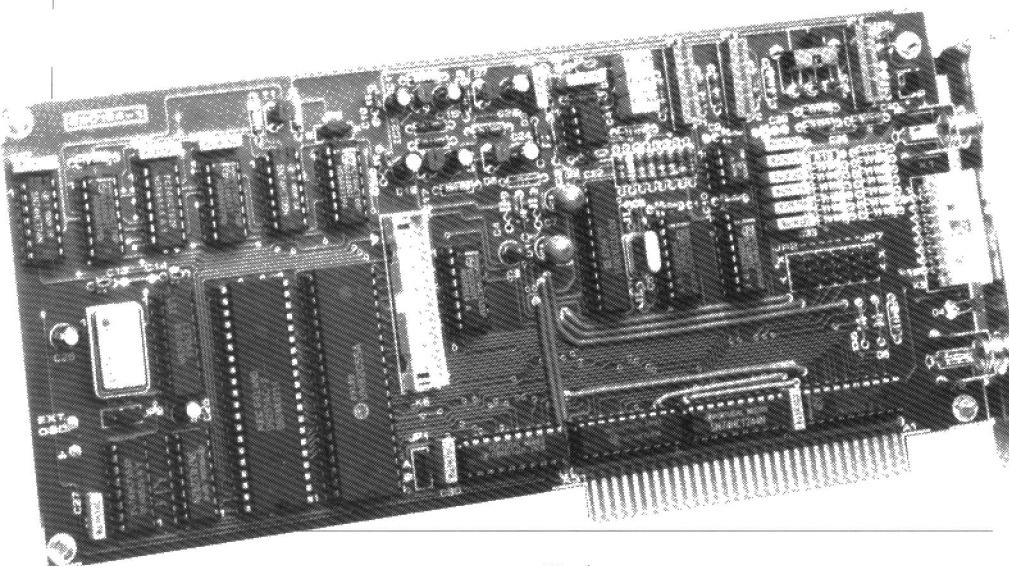


Fig. 3c. Track layout (mirror image) of the solder side of the board.





The calibration is equally important on channel 0, since the passive attenuator used here may give rise to measurement errors. That is why the program calculates the exact attenuation for each attenuator position. The switching between the attenuation factors is performed by multiplexer IC12. Attenuator position '0' corresponds to a measurement range in which voltages up to 0.1 V can be measured. The highest measurement range, 300 V, is selected by position '7'. All positions between '1' and '7' must be calibrated one by one in the 'Learn' routine.

Since the results of the calibration are stored in a file, the software is capable of accurately determining the values of the input voltages every time it is used. If the attenuation changes after a while owing to ageing effects, the correction factors may be updated simply by running the 'Learn' routine. A further advantage of the software-controlled calibration is that the actual attenuator can be kept relatively simple, and based on resistor values from the E96 series.

The 'Learn' option is relatively simple to use. Connect a test voltage of about half the maximum value to the relevant analogue input. Monitor this voltage with an accurate digital voltmeter (DVM). Select the 'Edit' option to open a small window in which the value of the input voltage is entered (see Fig. 6). This input voltage is read from the DVM. Next, the software computes the conversion factor and the maximum input voltage that may be applied to the input in this range before the ADC starts to produce overflows. Overflows must not occur until the input voltage exceeds the maximum level defined for the particular range. If the maximum measurement value is not reached in a particular range, the relevant resistor in the attenuator must be made a little smaller. If this is not done, the maximum level can never be measured, making it impossible for the autoranging function to work properly (remember, the software does not select the next higher range until the maximum level in the currently used range is exceeded).

### Update

When all measurement ranges (and channels) have been calibrated, the conversion factors may be written to a file on disk. This is accomplished automatically on selection of the 'Update' function. The conversion fac-

tors are stored in a file called `RATIO.CFG` for use by the program when this is started.

After this calibration procedure, the card is ready for use. It is recommended to store the different `.CFG` files on a separate diskette for use as back-ups when, for some reason or other, the files on the hard disk or the working copy of the floppy disk, are lost or corrupted (which would force you to go through the calibration routine again).

### PCV

To start the PC Voltmeter, simply select the option 'PCV' from the main menu. The result is shown in Fig. 7: the measured value is displayed in the form of large numbers on the screen. Below the voltage indication is a bargraph showing a corresponding value. The associated menu allows a number of preferences to be set. For example, the 'Sound' option enables a short beep to be produced when an overflow occurs. The optional filter function uses an algorithm to produce an average measurement value on the basis of a large number of measurements, thus reducing the risk of errors to a minimum.

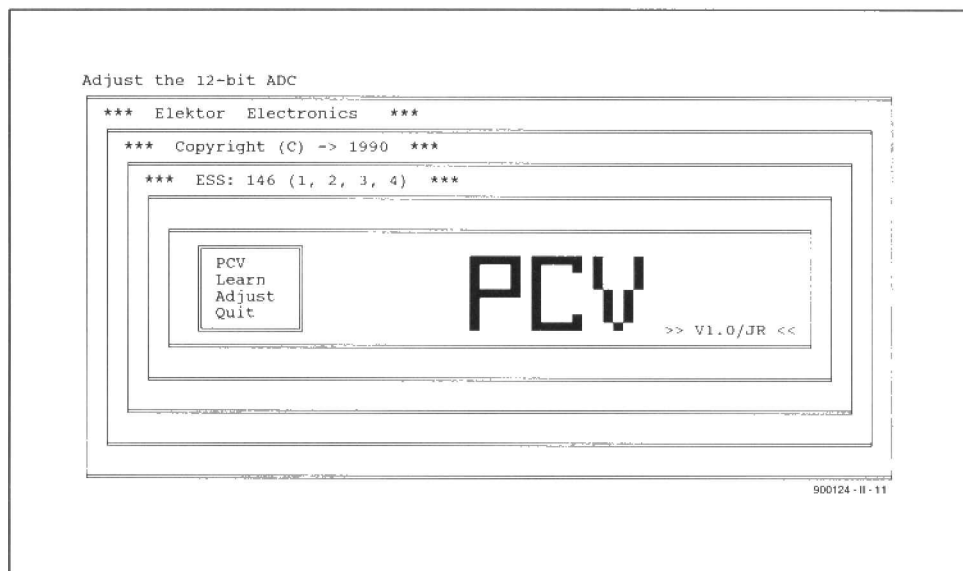


Fig. 4. Screenshot of the PCV main menu.

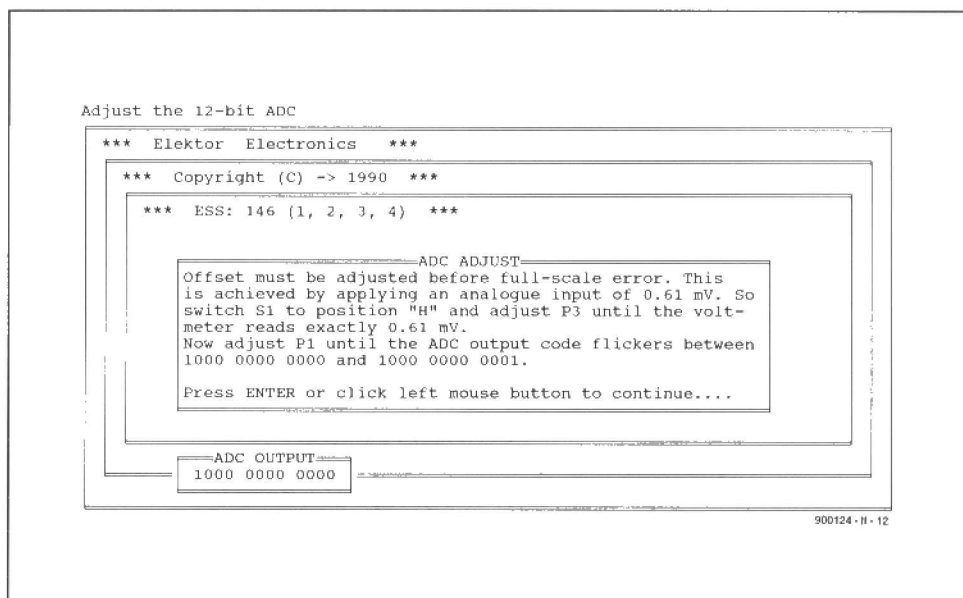


Fig. 5. On selecting the 'Adjust' option from the above menu, you enter a guided calibration procedure for the ADC.

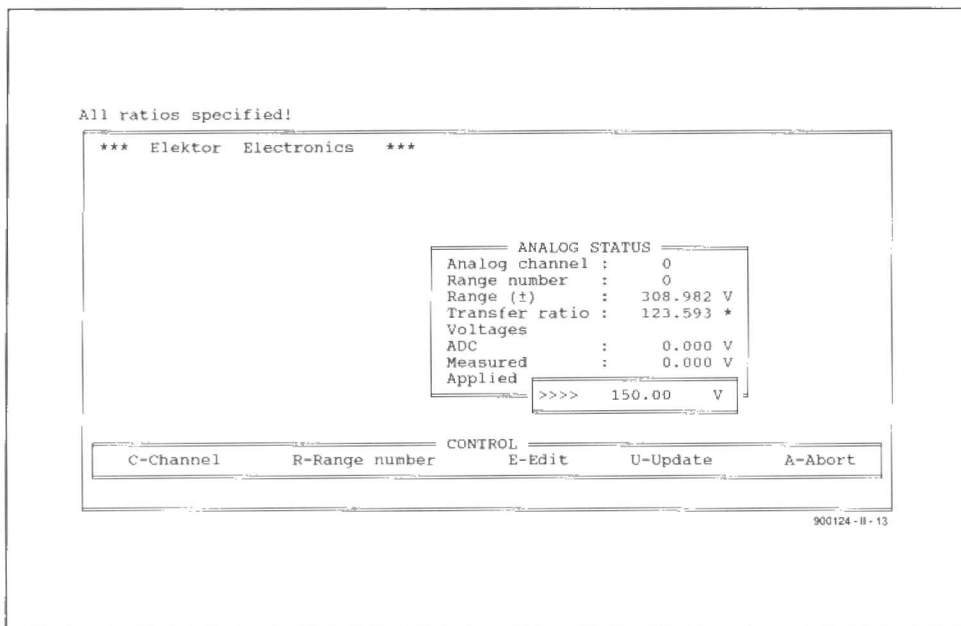


Fig. 6. The 'Learn' sub-menu of PCV is used to calibrate the ladder attenuator on the card.

The 'Channel' function enables you to select the channel of which the measurement results are shown in the large window.

Finally, a maximum input voltage level may be defined individually for each channel. A screen indication is provided when this value is exceeded. This indication takes the form of an exclamation mark (!) in the eight small windows at the bottom of the screen, a short beep, and a special 'Check-Lim' indicator in the large window.

### Quit

When the 'Quit' option is selected, the most recent settings are stored in the file PCV.CFG. These settings are called up automatically by PCV when the program is started.

## PCF, the PC-controlled Frequency/Pulse Meter

The PCF.EXE program is used for all time-related measurements on digital signals. As al-

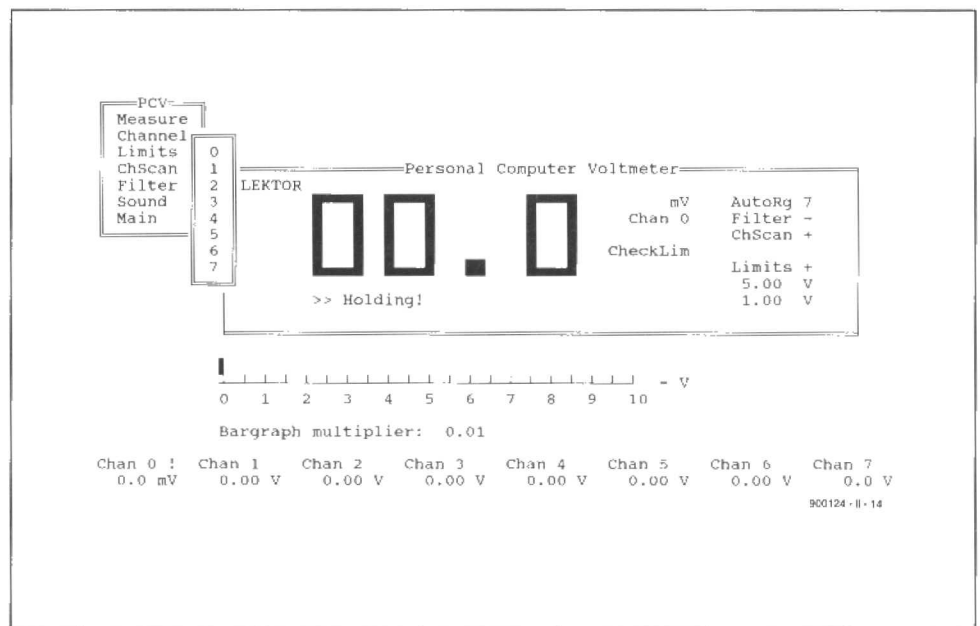


Fig. 7. The PCV in action. The display shows a large voltmeter indication as well as a bargraph read-out.

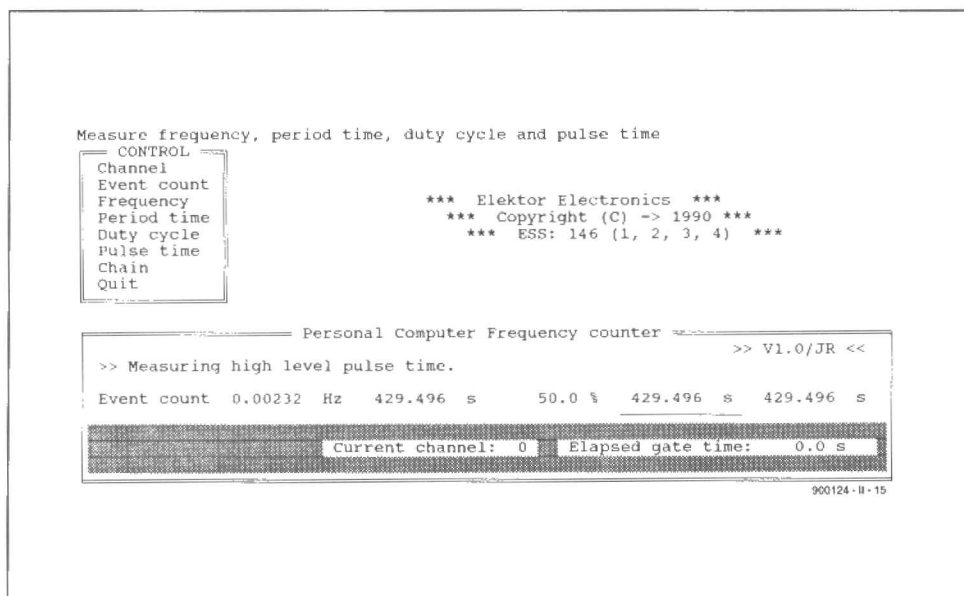


Fig. 8. The PCF function of the software is used for all time-related measurements.

ready mentioned in part 1 of this article, the available measurements are very accurate, covering the basic signal parameters frequency, period time, pulse/pause (on/off) ratio, and pulse time.

The program PCF.EXE does it all. Like PCV, it is user-friendly and features menus as well as windows for the measurement results. The menu allows you to select frequency measurement, event count, period time, duty cycle, or pulse time of the input signal. The screen shows the most recent results obtained from a measurement. These results are not updated until the relevant measurement is performed again. To keep you informed about what is being measured, the current type of measurement is underlined.

The event count and pulse time measurement each offer two submenus which allow the trigger edge and the on or off time to be selected respectively. The desired input channel is also selected via a submenu.

During the measurements, the measure-

ment window indicates the current channel and the lapsed gate time. The latter indication is particularly useful for measurements involving relatively long gate times. When an option is selected that requires additional information to be entered via a submenu (for instance, the 'Channel' option which takes the channel number in this way) the measurement window shows the indication 'Waiting for instructions!'. The relevant measurement does not start until you have entered the requested additional information.

The last menu option, 'Chain', provides an 'all-in-one' type of measurement, returning values on frequency, duty cycle, period time and pulse time (pulse 'on' as well as pulse 'off'). Since it has little meaning in the case of continuous signals, the event count function is excluded from the 'Chain' measurement, which, without doubt, is a good starting point for most measurements. ■



# PHONES IN THE AIR

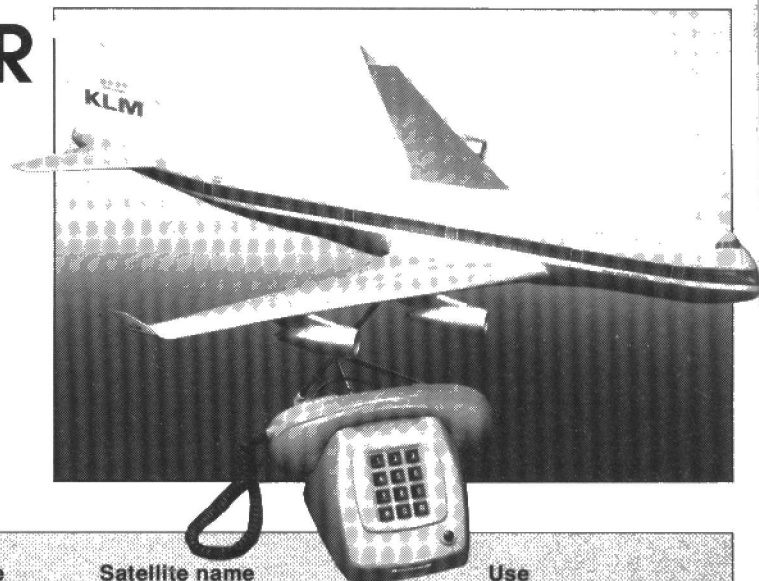
Telephones for use on board aircraft, employing satellite systems around the globe, must be the ultimate in mobile phone use. What was once considered to be feasible only in the realms of Gerry and Sylvia's puppetry is now common practice thanks to technological advances in the last few years.

**Bill Higgins**

A number of systems are currently being planned to provide telephone communication from aircraft for use via satellites to anywhere with telephone contact. One such system that is currently being launched is called 'Skyphone'.

## What is Skyphone?

Skyphone is a telephone service provided by a consortium formed by British Telecom International, Norwegian Telecom and Singapore Telecom. It can be used in passenger airliners and private jets. Calls can be initiated in either direction, i.e., air to ground transmission or ground to air transmission. Inmarsat satellites are used to afford coverage around the world, from aircraft in flight.



Region	Longitude	Satellite name	Use
AOR	26° W	Marecs B2	Operational
AOR	18.5° W	Intelsat V (MCS)	Dual
AOR	15° W	Marisat F1	Spare
IOR	63° E	Intelsat V (MCS)	Operational
IOR	60° E	Intelsat V (MCS)	Dual
IOR	73° E	Marisat F2	Spare
POR	180° E	Intelsat V (MCS)	Operational
POR	177.5° E	Marecs A	Dual
POR	176.5° E	Marisat F3	Spare

*Note: AOR to be widened to the West, when Marecs B2 will move from 26° W to 55.5° W.*

Table 1. Positions and usage of satellites employed for airborne telephone services.

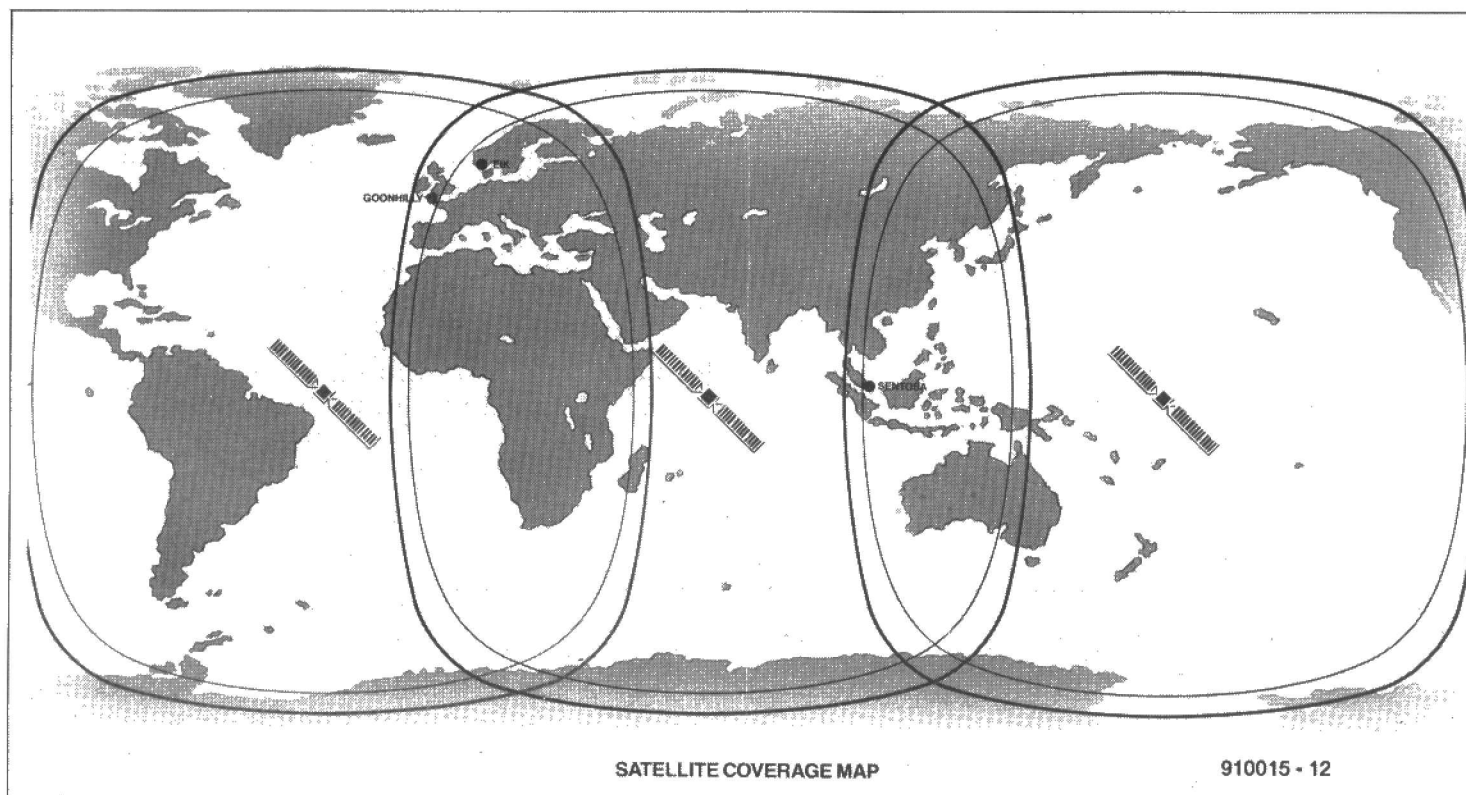


Fig. 1. Map showing Skyphone service coverage based on 0° and 5° angles of aircraft elevation at ground level. (source: British Telecom).

Region	Location	Operator
AOR	Goonhilly	British Telecom
POR	Sentosa	Singapore Telecom
IOR	Eik	Norwegian Telecom

Table 2. The three earth regions, Atlantic, Ocean, Pacific Ocean and Indian Ocean are served by different ground stations.

## Technical considerations

Signals from the system on board aircraft are relayed via an Inmarsat satellite in geostationary orbit, to a Ground Station for connection by the appropriate land based telecommunications company.

### Satellites

Inmarsat uses geostationary satellites in three geographical regions of the Atlantic, Pacific and Indian Oceans. For each region, a working pair, known as a dual, and one spare satellite are employed. Table 1 lists the nine satellites that are used.

### Ground stations

Connection to the ground network is via Ground Stations within each satellite region, as shown in Table 2. The uplink/downlink division and frequency band used in the aeronautical satellite system are given in Table 3.

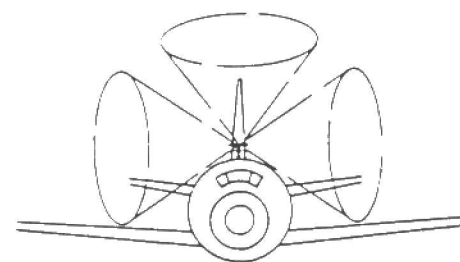
Within the Atlantic Ocean Region (AOR), calls are routed by British Telecom International via their Ground Station at Goonhilly. British Telecom's Skyphone ground network is shown schematically in Fig. 3. The station at Goonhilly houses equipment that separates telephone signals, including routing and billing signals, from the SHF link via the satellite. Links to London are normally in digital form to tie into the International Digital Switching Equipment (IDSE). Air traffic controls are linked directly to voice and data channel equipment at Goonhilly.

As might be expected, operator and customer services are linked to both Goonhilly and IDSE in London. A voice coding rate of 9.6 KBit/s is used for passenger and operational services.

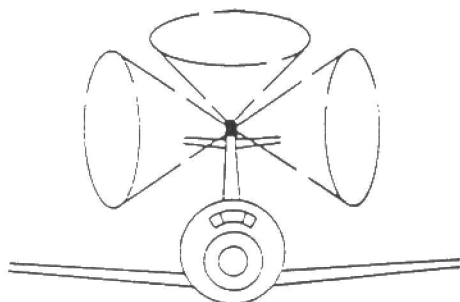
Similar setups are provided by Norwegian Telecom using their Ground Station at Eik to serve the Indian Ocean Region (IOR), and by Singapore Telecom using Sentosa Ground Station to serve the Pacific Ocean Region (POR).

### Equipment on board aircraft

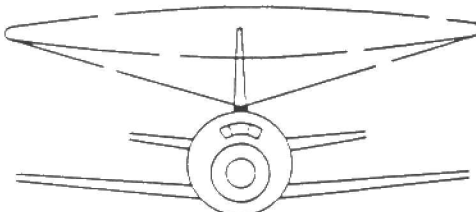
Airborne equipment is manufactured by a number of companies, mainly within the UK and USA. Table 4 lists equipment along with manufacturer and locations.



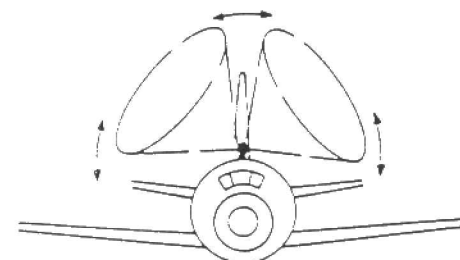
Blade antenna



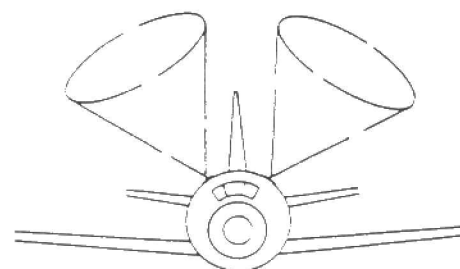
Tail-mounted antenna



Low-profile plate antenna



Mechanically steered antenna



Conformal side-mounted antenna

910015 - 11

Fig. 2. Some currently available antenna options for aircraft. (source: Racal Avionics).

### Antennas

Various designs of antenna are available to be connected to the outside of aircraft. Each design has its own characteristics including scan coverage patterns of five types of antenna (see Fig. 2).

#### Blade antenna

This type normally has high gain (12 dBi) with narrow beam width. It is used on a number of wide body aircraft such as the Boeing 747.

#### Tail-mounted antenna

Basically, this is a customized version of the



Use	Up/Down link	Frequency	Radio band
Ground Station	up	6 GHz	C
Ground Station	down	4 GHz	C
Aircraft Earth Station	up	1.6 GHz	L
Aircraft Earth Station	down	1.5 GHz	L

Table 3. Frequency and radio band assignment for the uplinks and downlinks.

Equipment	Manufacturer	Town/Country
<b>Antennas:</b>		
Lo & Hi Gain	Ball Aerospace	Boulder, Colorado, USA
CMA-2100	Canadian Marconi	Kanata, Ontario, Canada
Mech. Steered	E-Systems	Greenville, Texas, USA
Lo-profile radome & side-mounted	Teledyne Ryan	San Diego, California, USA
<b>Avionics:</b>		
E-Sat 300A	E-Systems	Greenville, Texas, USA
Sattfone	Honeywell	Phoenix, Arizona, USA
Sattfone	Racal	London, England
Satcom 900	Rockwell-Collins	Cedar Rapids, Iowa, USA
<b>Cabin equipment, handsets &amp; PABX</b>		
—	GEC sensors	Basildon, Essex, England
—	Global Wulfsberg	Irvine, California, USA

Table 4. Overview of UK- and USA-based manufacturers engaged in the production of airborne telephone equipment.

blade antenna. It is sited on top of the aircraft vertical stabilizer. The tail-mounted antenna is currently used on Gulfstream-2, -3, and -4 series of aircraft. Plans for its use on the Falcon 900 are under way, and it could be used on Lockheed L-1011 Tristar and other three-engined aircraft.

#### Low-profile plate antenna

This type is top-mounted and consists of 32 identical elements of about 3½-inch long placed in a rectangular grid of 8 elements long by 4 elements wide, enclosed in an aerodynamically shaped radome.

#### Mechanically steered antenna

This is a high-gain single-helix antenna that is situated on a pedestal. Coverage is about 360° azimuth and +90° to -30° elevation by means of an avionic signalling control system. Pedestal and antenna are both enclosed in an aerodynamically designed radome.

#### Conformal side-mounted antenna

This antenna is mounted on two sides of the aircraft fuselage to conform to its contours.

### Ring off

Things are happening at a fast pace in the development of services for passengers in aircraft. This article, although only an introduction to the operation of a complex system, may well be of use to readers, either as possible users of telephone equipment on board aircraft, or as people that may be involved in future designs and manufacture of systems and components.

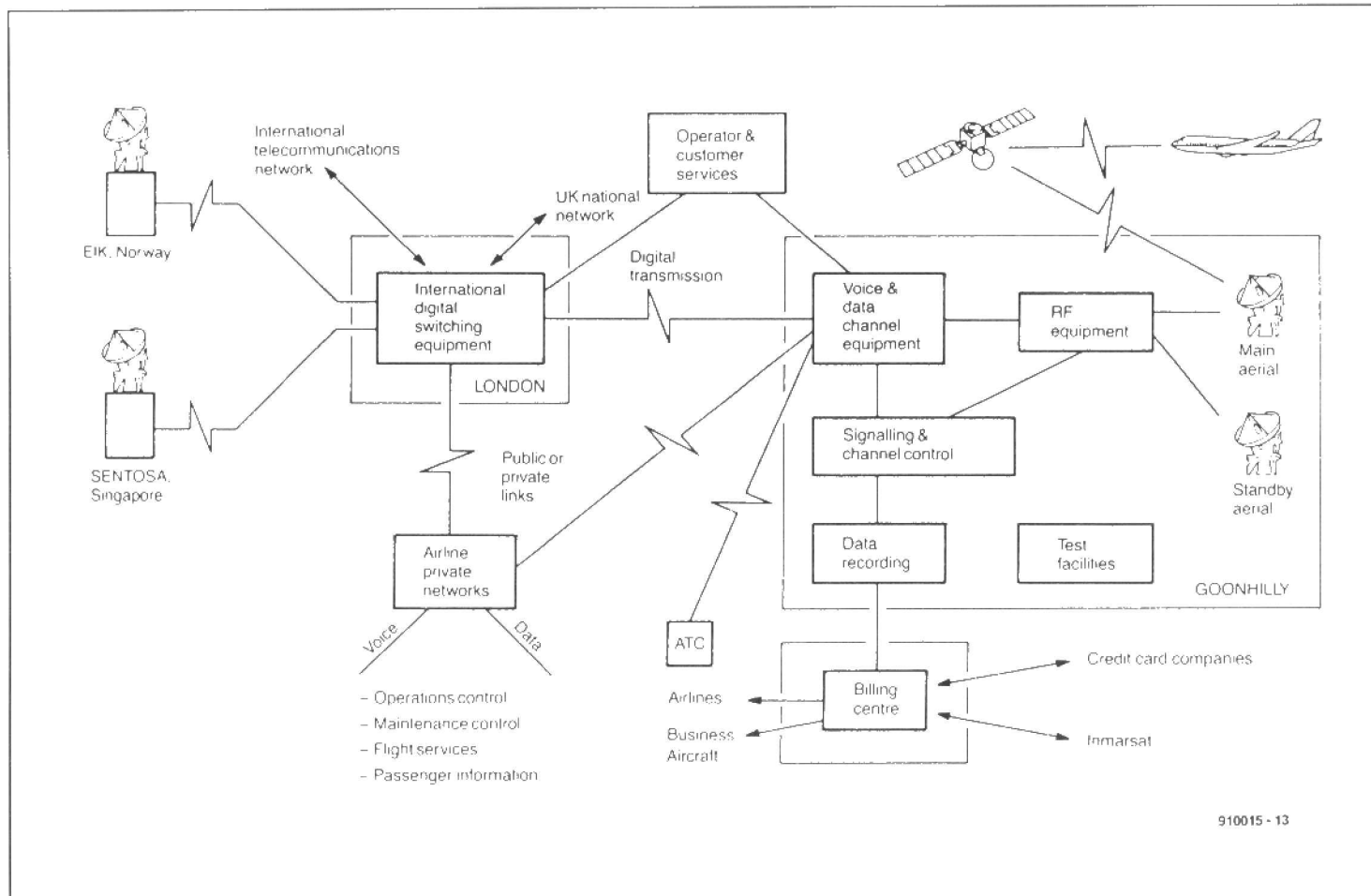


Fig. 3. Structure of the Skyphone ground network. (source: British Telecom).

# MEASUREMENT TECHNIQUES (4)

by F.P. Zantis

**This month's instalment deals with a very important measurement: that of resistance. This measurement is important not only in faultfinding, but also in design and development. It is, unfortunately, not possible to deal with the gamut of methods available: only the most common ones will be discussed**

**V**IRTUALLY all multimeters have several ranges for measuring ohmic (also called true or d.c.) resistance. The battery provided in analogue types is there for one purpose only: the measurement of resistance. The two most common methods of measurement use either a constant-voltage source or a constant-current source.

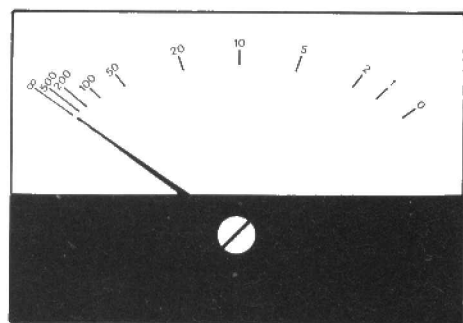


Fig. 24. An analogue meter becomes difficult to read at the left-hand side of the scale.

In the first, a constant voltage,  $U_c$ , is applied across the component under test: the resulting current,  $I_r$ , is used as the basis of the resistance measurement:  $I_r = U_c / R_x$ , where  $R_x$  is the resistance of the component under test. Since  $I_r$  is inversely proportional to  $R_x$ , a separate scale is required, which is calibrated in ohms (or multiples thereof) and runs

from right to left, that is, "0" is at the right-hand side of the scale—see Fig. 24. It should be noted that accurate measurements are only possible over the right-hand half or three-quarter of the scale.

The basic circuit for this method of measurement is shown in Fig. 25. The "0" value (meter terminals short-circuited) is set with

the resistance measurement:  $U_r = I_c R_x$ . Note that in this method  $U_r$  is directly proportional to the resistance. A separate scale is, therefore, not required. Moreover, the scale division is more linear, so that the values of resistance may be read fairly accurately over the entire scale.

Small or large resistance values cannot be measured accurately with either of these methods. A Wheatstone bridge or a comparison method must be used for these.

## Component testing with an ohmmeter

Most ohmmeters may be used for testing semi-conductors, provided that the potential at the test terminals is sufficiently high. A diode has a very large resistance when the test leads are connected across it in one way and a much smaller one, depending on the type of diode, when the test leads are reversed. In the first case, the diode is reverse-biased and in the other, forward-biased. The forward-bias resistance of point-contact diodes is considerably higher than that of junction diodes. Measurements of this nature indicate only whether the diode is functional or defect: other than that, they do not show how the diode will behave in a circuit.

Testing of transistors must be done in six stages—see Fig. 27. The resistance between emitter and collector is high in both directions. That between base and collector or emit-

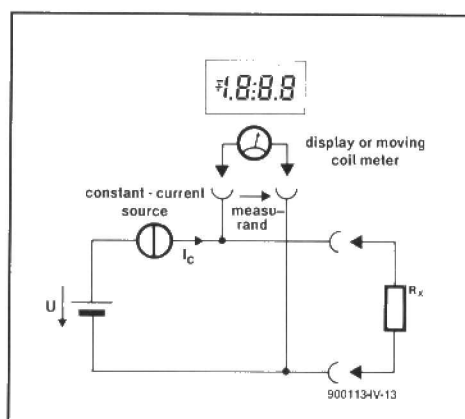


Fig. 26. Basic circuit for constant-current measurements.

the aid of the potentiometer. This obviates any circuit properties affecting subsequent measurements.

The fundamental circuit for constant-current measurements is shown in Fig. 26. In this method, a constant current,  $I_c$ , is passed through the component under test and the consequent voltage,  $U_r$ , across it is the basis of

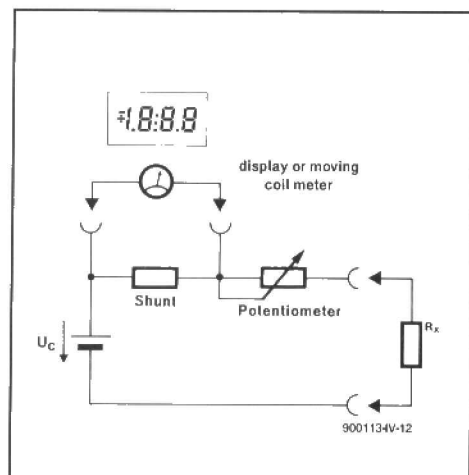


Fig. 25. Basic circuit for constant-voltage measurements.

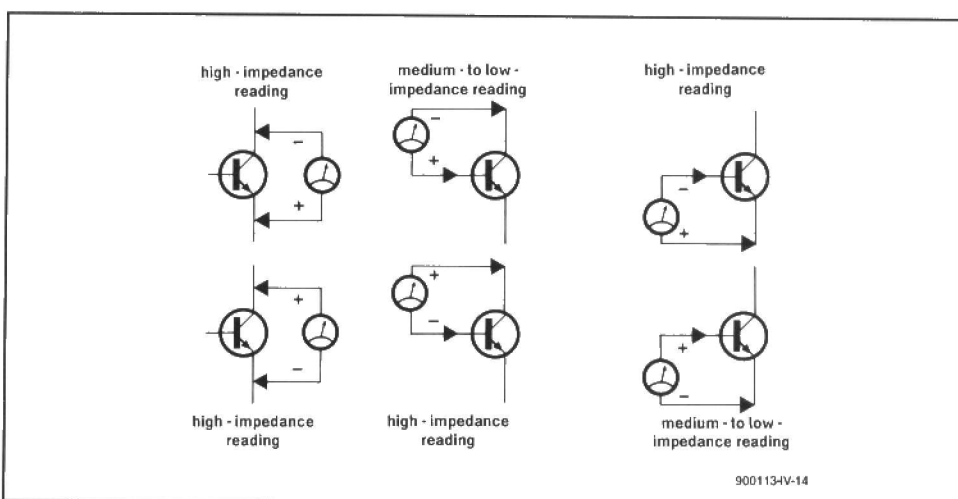


Fig. 27. Testing a transistor with an ohmmeter requires six measurements.



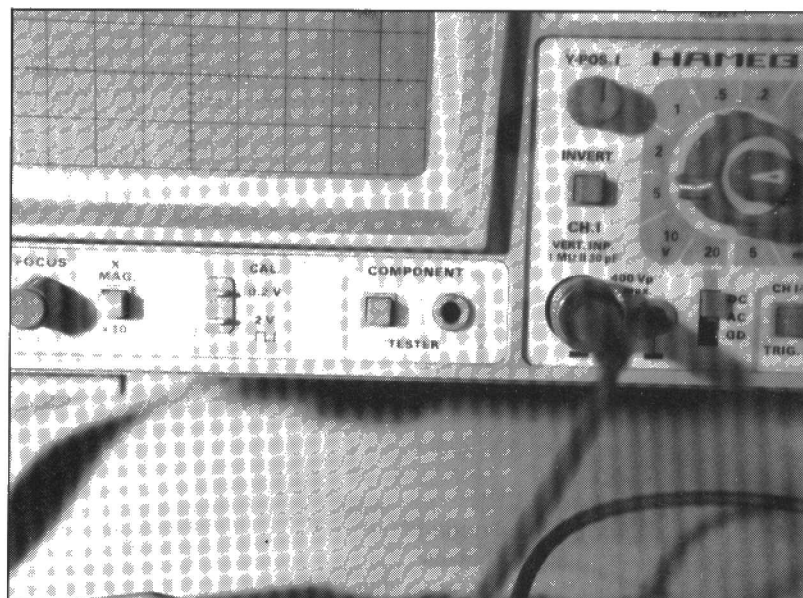
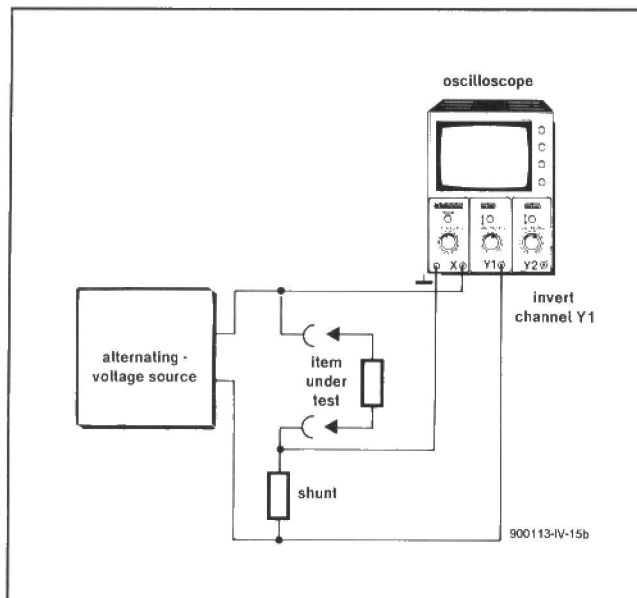


Fig. 28. Component tester: (left) test set-up and (right) incorporated in an oscilloscope.

ter is small in one direction and large in the other. The measured values depend on the applied voltage and current, as well as on the ambient temperature. It is thus not possible to measure absolute values, but short-circuits and open-circuits are, of course, indicated. When transistors are tested in-circuit in this manner, the effect of surrounding components must, of course, be taken into account. For more accurate measurements, the transistor should be removed from the circuit.

## Component tester

On the basis of the foregoing, special component testers for use with, or incorporation in, oscilloscopes have been developed as shown in Fig. 28. The basic circuit of the tester is fairly simple: a low alternating voltage, drawn for instance from a mains transformer, is used as the supply for the series network of component under test and shunt resistor. The alternating voltage is used as the horizontal time-base, while the potential drop across the shunt resistor is used for the vertical deflection of the electron beam. When the component tester is in use, the internal time-base of the oscilloscope is, of course, switched off.

The voltage drop across the shunt resistor determines the current through the component under test. The screen of the oscilloscope shows the  $I/U$  characteristic ( $U$  in horizontal direction), and thus the resistance curve of the component under test. No reference is provided, so that the trace only shows the relative resistance of the component under test.

Since the component tester is so simple, it is possible to use it with, or build it into, any oscilloscope whose time-base can be switched off and which has an additional X-input available.

Note that since the earth potential must be at the centre between component under test and shunt resistor, the current trace is inverted. In a number of oscilloscopes, the Y-channel can, however, be inverted, so that

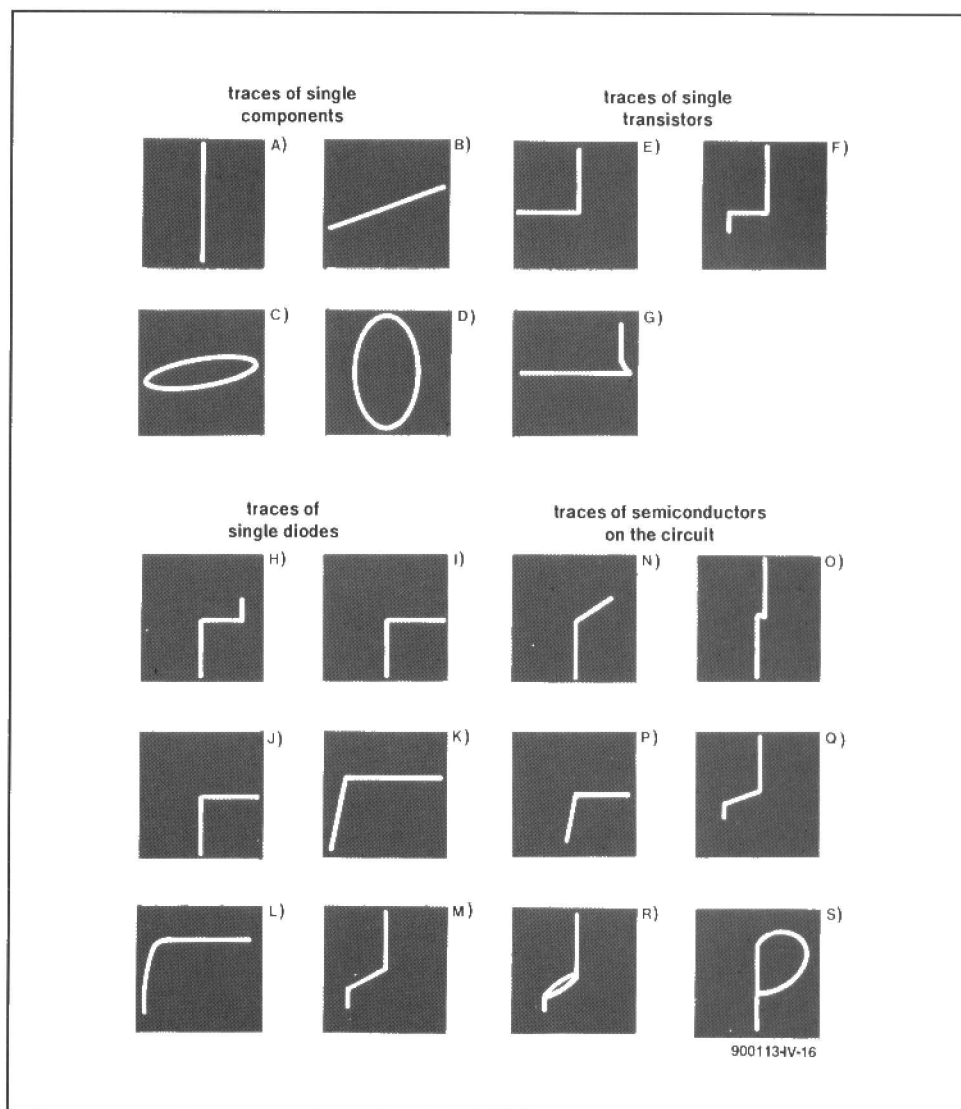


Fig. 29. Traces obtained from measurements with a component tester: A) test terminals short-circuited; B) true resistance; C) inductor; D) capacitor; E) base-collector junction of a transistor; F) base-emitter junction of a transistor; G) emitter-collector junction of a transistor; H) zener diode whose zener voltage is lower than the maximum test voltage; I) zener diode whose zener voltage is higher than the maximum test voltage; J) silicon diode; K) germanium diode; L) rectifier; M) thyristor whose gate is connected to its anode; N) parallel network of diode and resistor; O) two diodes connected in anti-parallel; P) series network of diode and resistor; Q) resistor in parallel with the base-emitter junction of a transistor; R) parallel network of resistor, capacitor and base-emitter junction of a transistor; S) diode and capacitor connected in parallel.

a correct trace is obtained.

There must be no voltage across the circuit or component under test, otherwise the measurement becomes meaningless.

Correctly interpreting the trace requires some practice, particularly when the measurement is carried out on a circuit.

If the component under test is a true resistance, there is no phase shift between the two deflection voltages and the trace is a straight line. The tilt of the line is a measure of the resistance: when this is 0, the trace is upright, when it is  $\infty$ , the trace is horizontal.

## Measurement of impedance

The component tester may also be used to determine impedance values. Capacitors and inductors cause a phase shift between the voltage across, and the current through, them, and thus between the deflection voltages. This gives rise to elliptical traces, the height and width of which are typical of the impedance of the component under test—see Fig. 29. Exact measurements are possible only if the relation between the horizontal and vertical deflection voltages is known. The vertical deflection is calibrated on all oscilloscopes. When the set value is divided by the value of the shunt resistance, the deflection on the screen is in A/div or mA/div. The X-deflection is often not calibrated, but the voltage at the relevant input may be measured fairly easily by switching off the time base and setting the trace exactly in the centre of the screen. Then deflect the trace to the nearest graticule division by applying a voltage to the X-input. The level of that voltage gives the value V/div. Once this has been determined, the values of voltage and current can be read directly from the traced characteristic.

Impedances may, of course, also be measured without the use of an oscilloscope and component tester. A sine-wave generator and an instrument that can process frequencies are then required. The component under test is connected to the generator, after which the voltage across it, and the current through it, may be measured. The impedance,  $Z$ , is determined from the relation  $Z = U / I$ . The true resistance must be deducted from the obtained value to arrive at the value of the reactance,  $X$ . In view of the phase shifts, however, this must be done geometrically, that is,  $X^2 = Z^2 - R^2$ . The values of reactance and impedance are valid only at the

frequency of the test signal.

The reactance,  $X_L$ , of an inductor is

$$X_L = \omega L = 2\pi fL,$$

whence,

$$L = X_L / 2\pi f.$$

The reactance and value of a capacitor are calculated in a similar manner

$$X_C = 1 / \omega C,$$

and

$$C = 1 / \omega X_C = 1 / 2\pi f X_C.$$

## Measuring the supply voltage

One of the most frequent measurements is checking the supply voltage of an equipment. Moreover, preliminary tests in design and development aim at deciding whether a given voltage- or current-source is suitable for the project in hand. Most supplies can be checked with three or four measurements of: e.m.f.; short-circuit current; internal resistance,  $R_i$ ; and, in the case of a d.c. source, the hum voltage,  $U_h$ . Most voltage sources provide a direct voltage or an alternating voltage with a frequency of 50 Hz. Both of these may be measured with a multimeter without any problem.

To measure the e.m.f., it is imperative that the source is not loaded: if the output impedance of the source is not particularly high, the input resistance of the multimeter may be ignored.

Measuring the short-circuit current is in many cases not recommended. It is better to determine the internal resistance, which in most cases will enable the short-circuit current to be calculated.

Measuring the internal resistance of a home-made regulated supply can be very revealing: for one thing, it shows how good the supply really is. A pretty good and simple way of determining  $R_i$  is possible with the circuit shown in Fig. 30. The source is loaded with a variable resistor that is set to a position where exactly half the e.m.f. is dropped across it. The drop across  $R_i$  must then be the same, which means that the internal resistance must have the same value as that presented by the variable resistance. Note that this

method is not suitable when the value of  $R_i$  is relatively high, because the current may then become relatively large. The method is, however, suitable for determining the input and output resistance of an electronic circuit.

The simplest way of determining the internal resistance of a voltage source is as follows and requires knowing two operating points. The first of these may be the e.m.f.,  $U_0$ . The second may be determined by loading the source with a resistance,  $R_1$ , whose value must cause the output voltage to be appreciably lower than the e.m.f. The internal resistance is then calculated from:

$$R_i = (U_0 - U_1) / (U_1 / R_1) = R_1 (U_0 - U_1) / U_1.$$

If, for example, the e.m.f. of an a.c. source is 25.2 V and the output voltage drops to 23.5 V when a load of 5.6  $\Omega$  is connected across the output, the value of the internal resistance is:

$$R_i = 5.6 (25.2 - 23.5) / 23.5 = 0.41 \Omega.$$

Note that the output current is then 4.2 A: this value must be lower than the maximum output current before current limiting sets in. As soon as current limiting takes place, the internal resistance rises rapidly, which invalidates the measurement.

## Compensating method of measurement

The smaller the internal resistance of a voltage source, the better regulated the output voltage. Electronically stabilized power supply units have a very small internal resistance, provided the maximum output current is not exceeded. Such small resistances cannot be measured by the methods described so far, at least not with any degree of accuracy. They can be measured accurately by the so-called compensating method, which requires some care in calibration, however.

The test set-up is shown in Fig. 31. The unit under test is loaded by a variable resistance,  $R_1$ , and the resulting current,  $I_1$ , is measured. The voltmeter indicates the difference,  $U_d$ , between the potential across  $R_1$  and the compensating voltage,  $U_{ref}$ , which is set by  $R_2$ . This resistance is varied until  $U_d = 0$ . At the same time, lower and lower ranges of the voltmeter are selected to make the calibration as accurate as possible. Then,  $R_1$  is

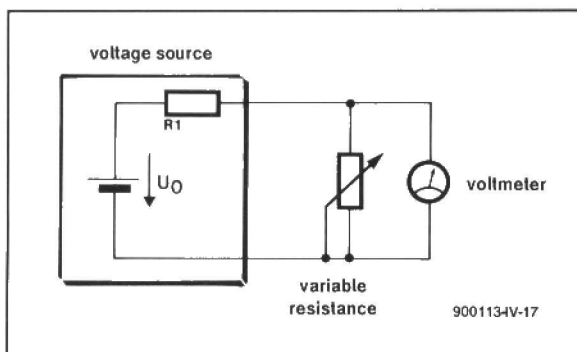


Fig. 30. A pretty good and simple way of measuring the internal resistance of a voltage source.

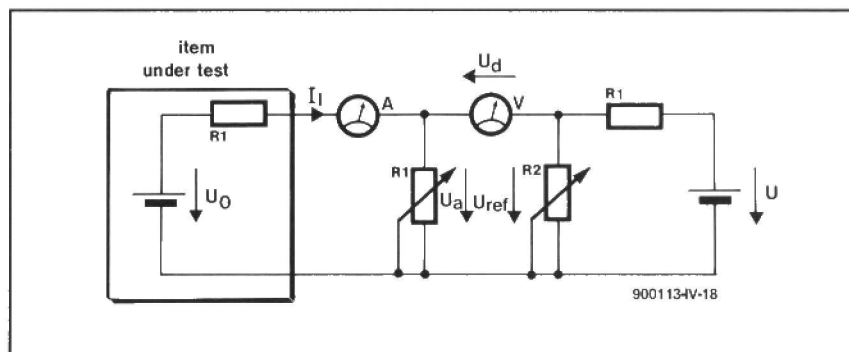


Fig. 31. Compensating method of measuring small internal resistances.

carefully varied in small steps. This will cause a change in  $I_1$  as well as in  $U_0$  as indicated by the two meters. The internal resistance is calculated by dividing the change in output voltage by the change in current.

### Measuring hum voltage

All d.c. supplies derived from an alternating voltage retain a certain amount of a.c., how-

ever small, superimposed on the direct voltage output. This a.c. component manifests itself as hum. The lower the hum level, the better the power supply, at least in this respect. The a.c. component can be measured by removing the d.c. with the aid of a capacitor. On oscilloscopes this is done by setting the input selector (AC/GND/DC) to AC. The a.c. component may then be displayed on the screen with very good resolu-

tion. Since the hum voltage is seldom sinusoidal, it is normally specified as peak-to-peak, and this is clearly seen on the screen.

Multimeters set to a.c. ranges also isolate the d.c. voltage from the input signal, so that only the a.c. component is measured. Since this component is normally not sinusoidal, the indicated value is only reliable if a true-r.m.s. multimeter is used.

(to be continued)

# DECADIC VOLTAGE DIVIDERS

by Ing. G. Peltz

**Designing decadic voltage dividers is not as simple as it may seem. One decade is not too difficult, but when a number of decade steps are to be selected by a rotary switch the design becomes rather more tricky. Or does it? In this article, an old divider circuit is rehased that otherwise may easily be overlooked in these days of microprocessor-controlled digital potentiometers.**

FIGURE 1 shows the basic circuit of a 3-decade voltage divider. Switches  $S_1$  and  $S_2$  are 2-pole, 10-position types, while  $S_3$  is a single-pole, 11 position type. Both  $S_1$  and  $S_2$  select two resistors at a time from a divider chain. The value of the parallel combination of these two resistors and the following chain is equal to that of a single resistor. This requirement is fulfilled when, for example, chain 1 contains resistors of value  $R$ , chain 2 contains resistors of value  $R/5$ , and chain 3 contains resistors of value  $R/25$ . Note that  $S_1$  and  $S_2$  are always displaced two positions with respect to each other.

Since the value of the parallel combination of the two resistors between the poles of  $S_1$  and the following chain is equal to that of a single resistor in the first chain, the voltage drop across each resistor is the same as the potential between the two poles of  $S_1$ , that is, the input voltage,  $U_r$ , divided by 10. Similarly, the potential across each of the resistors in the second chain is  $U_r/100$ , and that across each of the resistors in the third chain is  $U_r/1000$ . This means that the output voltage (with respect to earth) may be selected in steps of a thousandth of  $U_r$ , depending, of course, on the tolerance of the resistors, which in this case must be 0.1%.

Figure 2 shows a practical application of the foregoing: two resistor chains and a potentiometer provide an accurate, variable voltage source. Potentiometer  $P_3$  may be replaced by a third chain of 47  $\Omega$  resistors.

A temperature-compensated zener diode provides a very stable reference voltage,  $U_r$ , of 6.8 V from the supply voltage,  $U_b$ .

The values of the two resistor chains may

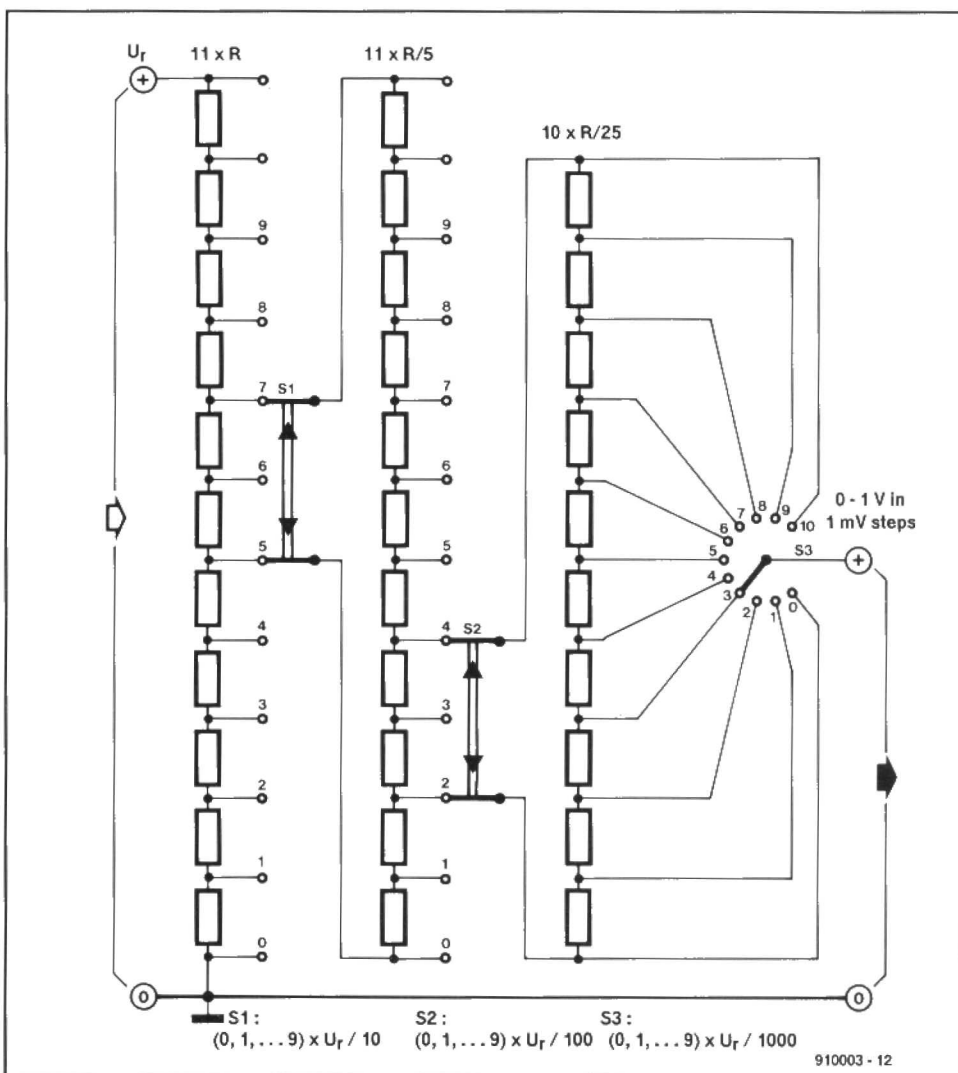


Fig. 1. Basic design of a decadic voltage divider.



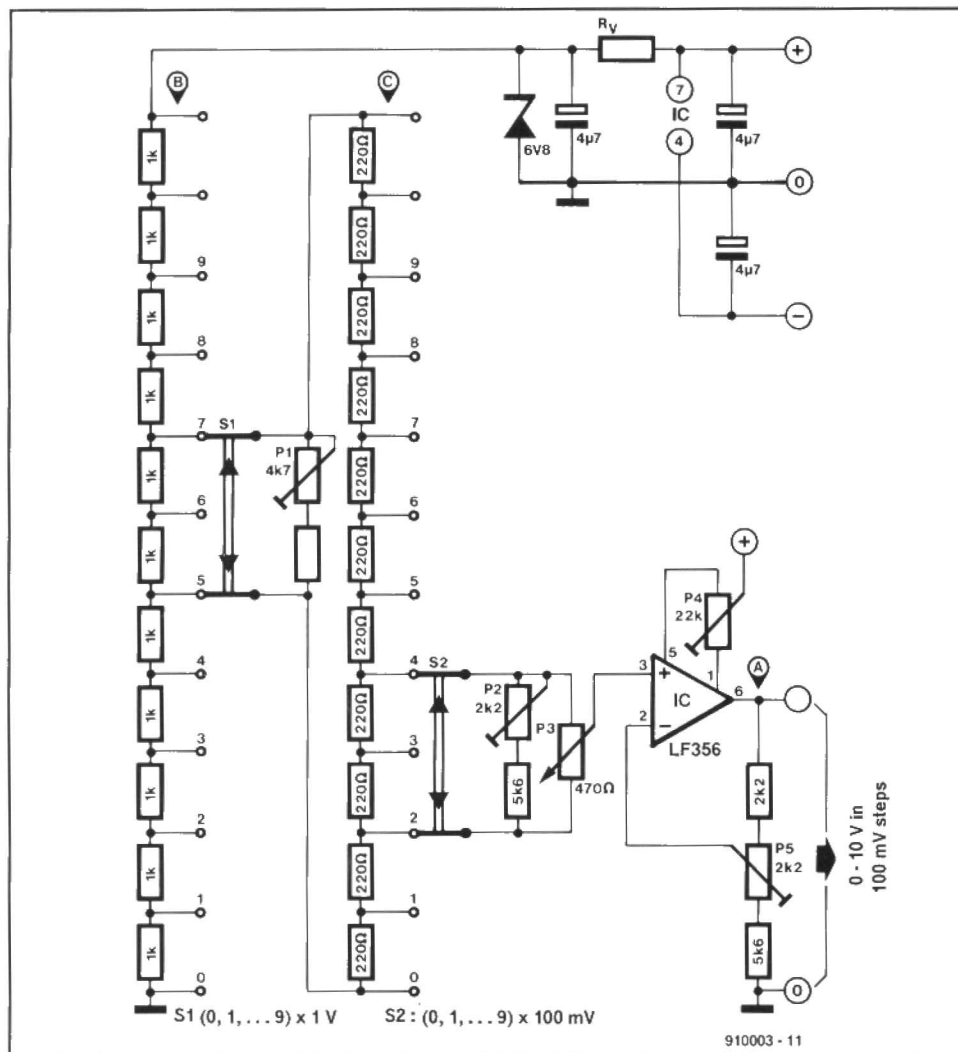


Fig. 2. Voltage source providing 0-10 V in 100 mV steps.

be adjusted by presets  $P_1$  and  $P_2$  respectively to give the second chain a total resistance of exactly 2 k $\Omega$  and "the third", that is,  $P_3$ , a value of 4 k $\Omega$ . If 2% resistors (of the same

batch) are used in the dividers, an overall accuracy of 0.5% is obtained. This accuracy will, of course, be even better if 1% or 0.5% resistors (from the same batch) are used.

The potential at the wiper of  $P_3$  covers a range of only 0-6.8 V and must not be loaded too heavily to avoid unacceptable errors. For that reason, the potential is applied to an opamp with FET inputs, which gives an output voltage range of 0-10 V preset by  $P_5$ .

The opamp is powered by an asymmetric voltage source:  $+U_b = 12-18$  V;  $-U_b = 5-10$  V.

Series resistor  $R_v$  in the positive supply rail has a value between 1 k $\Omega$  and 2.2 k $\Omega$ , depending on the level of the supply voltage; it carries a current of about 5 mA.

Except for  $R_v$ , all resistors should be metal film types with a temperature coefficient,  $T_k$ , not greater than  $\pm 50$  p.p.m. and a tolerance of  $\pm 1\%$  or better. Presets  $P_1$ ,  $P_2$ ,  $P_4$  and  $P_5$  are multturn cermet types, while  $P_3$  is a good-quality wirewound type or a 470  $\Omega$  resistor chain as in Fig. 1. The switches should also be high-quality types.

## Calibration

For calibration, a digital multimeter with a 4  $\frac{1}{2}$  digit display is required. Set all presets to the centre of their travel, and  $P_3$  and the switches to their lowest position.

Turn  $P_4$  until the output voltage is 0 V with respect to earth.

Check that the level at B is exactly the same as the zener voltage.

Turn  $P_1$  until the potential at C is exactly one tenth of the voltage at B.

Set  $S_1$  to position 1, i.e., between terminals 1 and 3, and turn  $P_5$  until a voltage of exactly 1.000 V is obtained at the output.

Adjust  $P_3$  for maximum output and then turn  $P_2$  to give an output of 1.100 V.

Reset  $S_1$  to position 0: the output should then be exactly 100 mV.

Since the controls affect one another slightly, the calibration needs to be repeated a couple of times.

## NEW DIGITAL/ANALOGUE MULTIMETER FROM ITT

THE new Type MX570 from ITT Instruments is a combined analogue/digital multimeter that offers auto-ranging on both the traditional analogue pointer and the digital LCD read-out.

The instrument is aimed at traditional multimeter users who appreciate the accuracy and unambiguity of a digital read-out, but who find that alternative analogue solutions on simple bar-graph displays lack the same response and 'feel' of a true analogue pointer.

Both the analogue and digital displays of the MX750 share the same auto/manual ranging and auto-polarity electronics, and yet the pointer response is not restricted by the sampling rate of the analogue-to-digital converter.

ITT products are manufactured at a number of locations world-wide and are available in most countries.

## NEW WAVEFORM GENERATOR FROM GOULD ELECTRONICS

GOULD has introduced the DWG-7000 digital waveform generator that covers the frequency range 10  $\mu$ Hz-10 MHz, and can produce both standard and arbitrary waveforms with a resolution of 100 ns per point. Internal memory is sufficient to store 8192 digital points. The vertical resolution is 12 bits.

Built-in standard functions include sine, square, triangle, d.c., positive ramp, negative ramp, positive pulse and negative pulse. All can be selected from the front panel or from a remote controller via IEEE-488 or RS 232 interfaces. A full complement of sweep functions is also available.

The DWG-7000 is suitable for all general purpose electronics applications.

Gould Electronics manufactures a wide range of electronic instruments, which are available in most countries of the world.



# LOGIC ANALYSER PART 2

by K. Nischalke and H.J. Schulz

## The busboard

The busboard does not look it, but it is the heart of the analyser—see Fig. 3. It can accept up to five other cards, each via a discrete connector. A sixth connector provides a link to the computer interface. The majority of the signals handled is common to all the boards, as is usual in the case of busboards. Only the five board-select signals, the 5-volt supply and the earth connections are individually provided for each card as is shown in Fig. 4 (Part 1).

## The clock

The fact that the analyser is provided with a clock frequency of 100 MHz indicates that it is not intended for measuring direct voltages or currents. It does not mean, however, that a 100 MHz signal can be applied to the input without further consideration. What in an analyser is called clock frequency is in other applications often a sampling frequency (as, for instance, in CD systems). According to Shannon's Theorem, the sampled signal may be reconstructed correctly only if the highest frequency of the input signal is not greater than half the sampling frequency. That is not all, however, because rectangular waveforms are used in the analyser that contain, apart from the fundamental frequency, a whole series of harmonics. For reliable sampling a digital input signal, a maximum fundamental frequency of, say, 30 MHz must be assumed. The most important, and also the strongest, harmonic is the third and that is then nearly equal to the clock frequency. In real terms, that means that the frequency range of the signals that are required to be transported over the metering leads extends to at least 100 MHz. That cannot be done reliably and without distorting the signals over even small distances, however, by means of some twisted cable terminated into croc clips. The analyser therefore uses an active probe, which is discussed below.

## The probe

From a purely electronics point of view, the probe (see Fig. 6) is very simple: a few resistors, two connectors and some buffers. Nevertheless, it forms an important link in the transport of the input signals to the analyser. It is, as it were, a "forward" input. The item under test may be connected to it with short leads, so that it only "sees" these leads and the probe input. This is fortuitous as the following example shows. Assume that a test lead has a capacitance of 10 pF (with many test leads, this is much higher). If the signal across the lead has a frequency of 30 MHz, the

lead represents a load of  $530\ \Omega$  on the signal source. The very short leads used here ensure very low capacitance. The load presented by the long cable following the buffers in the probe is not reflected on to the signal source.

The buffers in the probe are of the familiar 245 type in the 74 series, but in ACT technology, that is, fast. The more usual types are not fast enough. Moreover, the ACT types have a high-impedance input, so that they present only a small load.

The outputs of the buffers provide a signal that is strong enough to bridge a 1 m cable. If a longer cable is required, more buffers must be added. The connectors of the probe are therefore designed to enable the probe and cable to serve as an extension lead. They carry, apart from the data lines, the 5-V supply and also a  $\pm 12$ -V supply to enable a probe to be constructed that can handle higher input voltages.

Populating the printed-circuit board—see

Fig. 7—is straightforward, but care must be taken to ensure that pin 1 of  $K_4$  is located correctly. Before the board can be mounted in the case, the cover must be prepared. One of the long sides must be given a recess through which  $K_5$  can be passed. The other long side must be given a slot through which the flat-cable can be passed. Note that this must be done before the second connector is fitted on to the cable. The photograph in Fig. 8 shows how these modifications should be carried out.

The board is fitted on to the inside bottom of the enclosure with two screws. The flat-cable can now be fitted to the connector, after which the top of the case can be put into place.

The connection between probe and item under test is made by a short length of flat-cable and a number of single-core leads terminated into a test clip. The flat-cable is terminated at both ends by a female connector fitted with a strain relief clamp. One of the

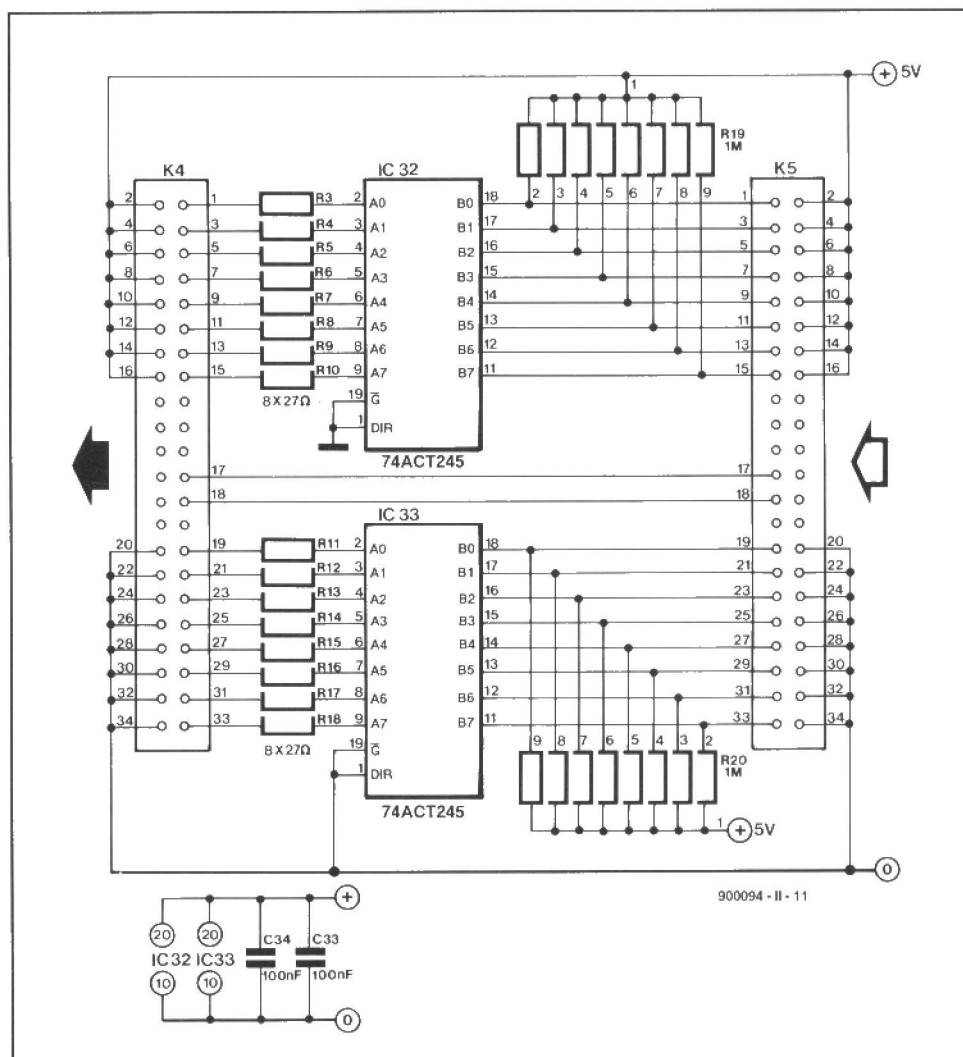


Fig. 6. Circuit diagram of the probe.

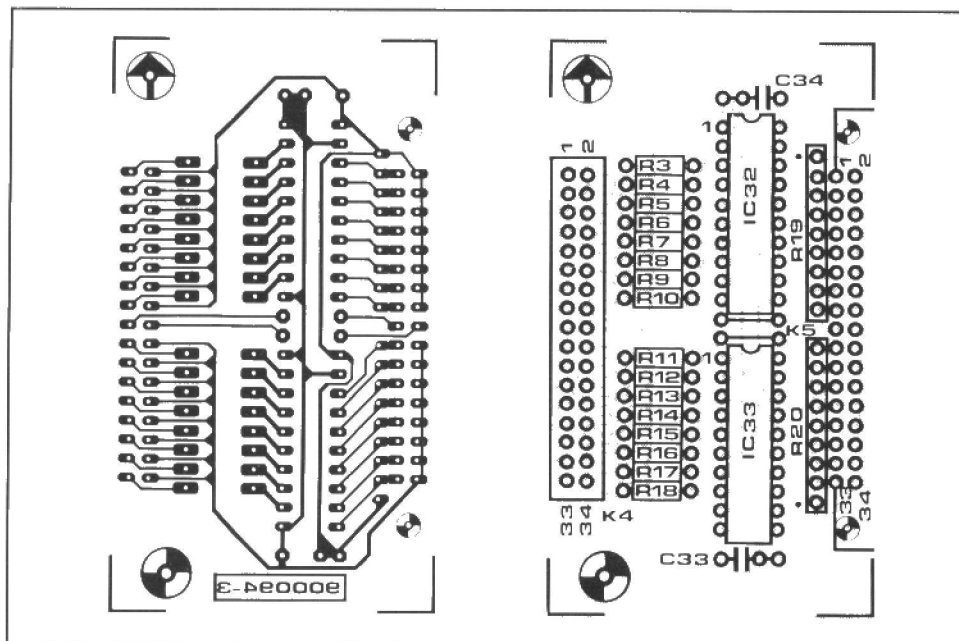


Fig. 7. Printed-circuit board for the probe.

## PARTS LIST

### Resistors:

R<sub>3</sub>–R<sub>18</sub> = 27Ω  
R<sub>19</sub>–R<sub>20</sub> = array, 1MΩ

### Capacitors:

C<sub>33</sub>, C<sub>34</sub> = 100 nF

### Semiconductors:

IC<sub>32</sub>, IC<sub>33</sub> = 74ACT245

### Miscellaneous:

K<sub>4</sub> = 34-way male box header  
K<sub>5</sub> = 34-way right-angle print header with ejector  
Four 34-way IDC sockets (three with strain relief clips)  
1 metre 34-strand flatcable  
16 red miniature test clips  
1 black miniature test clip  
Enclosure, 50×25 mm e.g.  
OKW A9010087; Bopla 410;  
Multibox 110  
PCB Type 900094-3

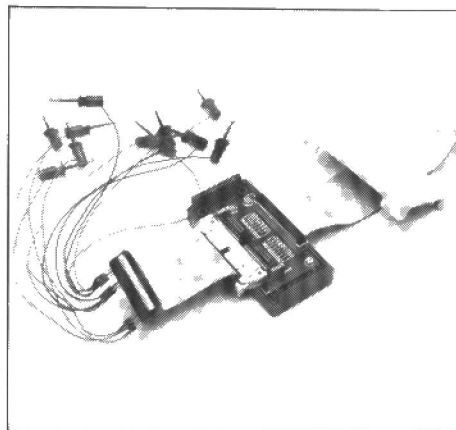
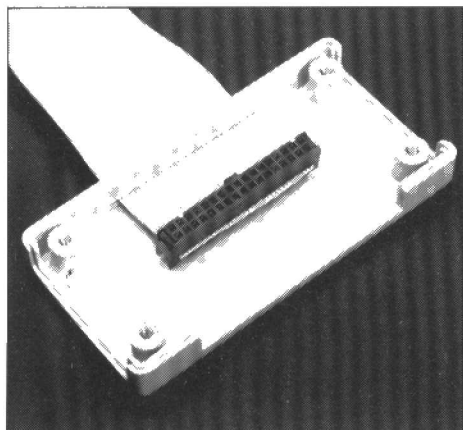


Fig. 8. (left) a slot and a recess have to be provided in the top of the enclosure; (right) general view of the probe and the required ancillaries.

sockets is connected to the probe, while the other is used as a multiple connector for the individual test leads. These test leads are terminated into wire-wrap pins that fit nicely into the socket. These pins may be bought from your local retailer or cut off contacts strips that normally serve as IC socket – see Fig. 8. The test cable is then soldered into one of the two buses. The other end of the individual leads, which should not be longer than 20 cm, is fitted with a test clip. The other bus remains unused except for one plug per probe where an earth connection is soldered.

## The RAM card

The RAM card is at the heart of the input signal processing; it writes and temporarily stores the data. The relevant circuit is straightforward as may be seen in Fig. 9. The input signals are passed to ICs 17, 18, 28 and 29.

Depending on the logic state of the 100/25 MHz signal at the S<sub>1</sub> input of the ICs, these devices function either as shift register or as latch. When the signal is high (25 MHz mode), the data present at parallel inputs AD are accepted into the registers of the ICs at every clock pulse. In this state, 16 input signals can therefore be processed.

When the 100/25 MHz signal is low (100 MHz mode), the four ICs function as shift registers that accept the logic state of input SR at every clock pulse. This means that only four inputs are left per RAM card, but these may be processed at a clock frequency of 100 MHz. Since the clock frequency can go up to 100 MHz, the clock signal is not carried via the bus board but via a short coaxial cable that connected the CLK input directly to the control board.

From the input shift register, the signal is split into two: one part goes to the word rec-

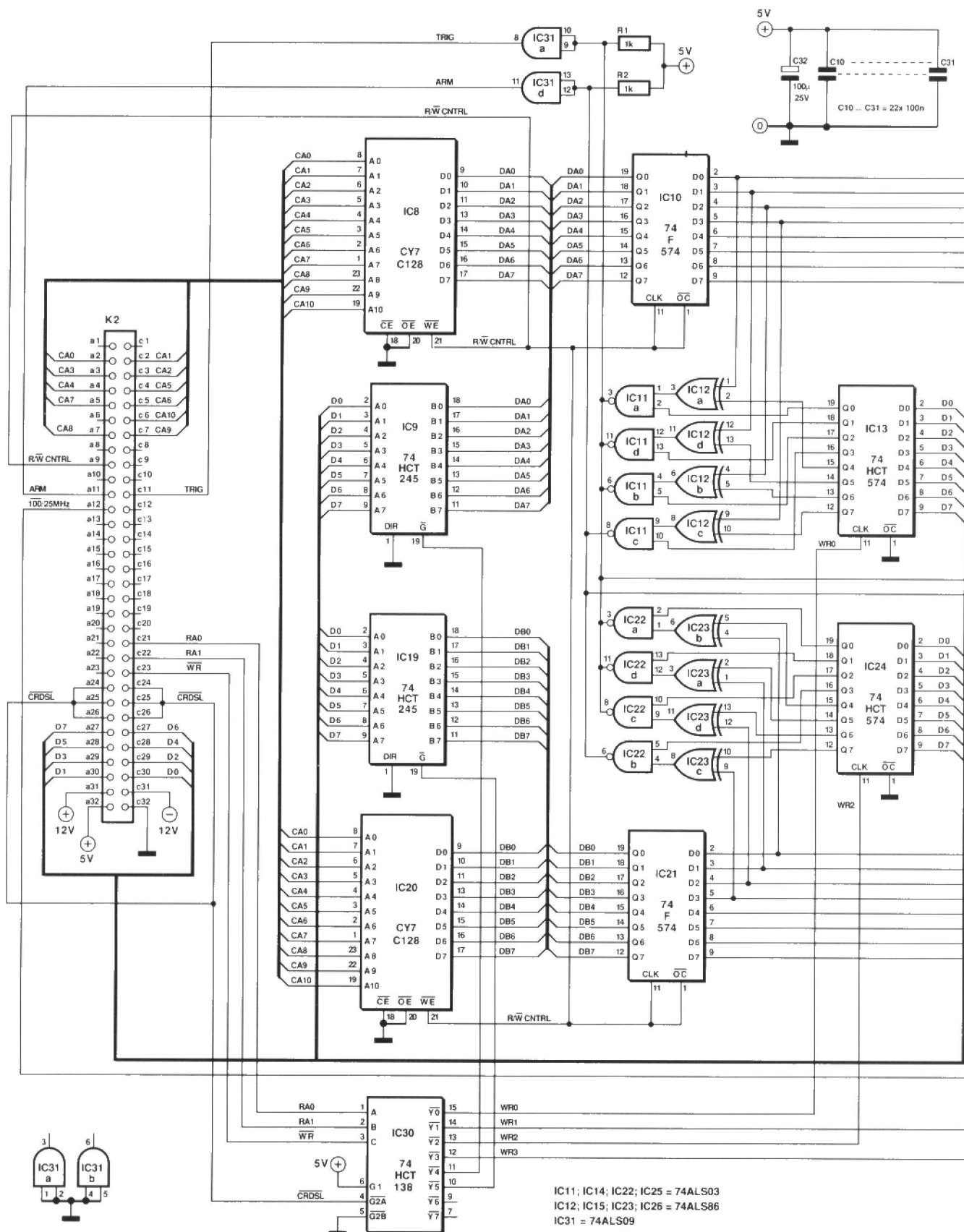
ognizer and the other to a latch formed by IC<sub>10</sub> and IC<sub>21</sub>. The three-state outputs of this latch ensure that the RAM can be read without any problems.

Furthermore, the latch ensures that in the 100 MHz mode the data are stable long enough to be written into the RAM. True, in the 100 MHz mode the data are offered at a frequency of 25 MHz, but in spite of that they remain stable for only 10 ns, which is too short for IC<sub>8</sub> and IC<sub>20</sub>, the RAM ICs. It is for that reason that they are first stored in the latch. The R/W signal from the control card clocks the latch and controls the RAM. The control board also provides the address lines that contain the address into which the data are written in the RAM. Every time this occurs, the address is increased by one.

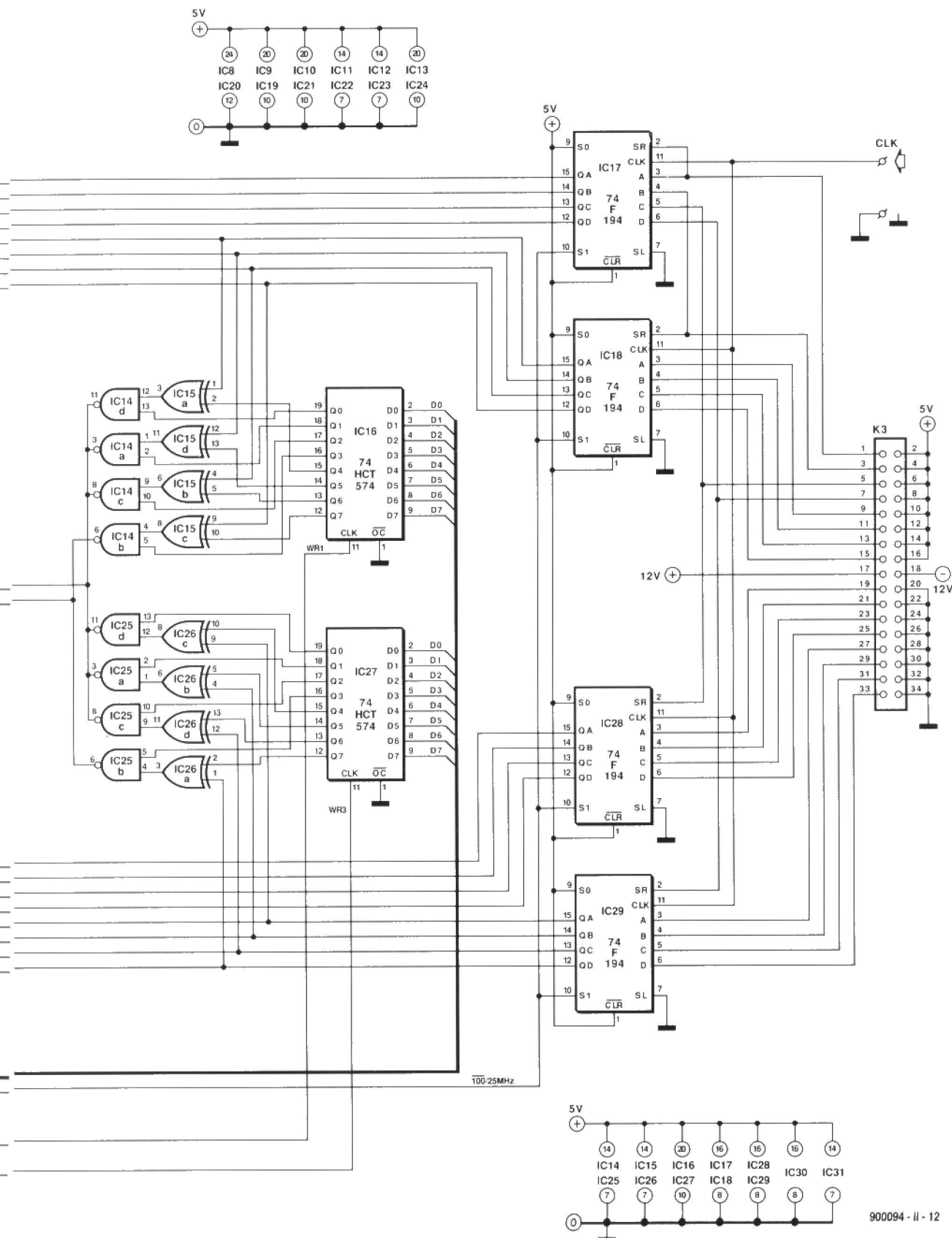
When the measurement has been completed, the R/W control goes high. The outputs of latches IC<sub>10</sub> and IC<sub>21</sub> are then high-resistance and the RAM is in the read position. The computer can then read the contents of the RAM address by address via three-state buffers IC<sub>9</sub> and IC<sub>19</sub>. Since only eight bits can be read at a time, the buffers must be addressed individually, and this is done via address decoder IC<sub>30</sub>. The two register address lines and WR determine into which register may be written and from which one may be read. The address decoder is also controlled by a card select signal to enable a distinction to be made between the RAM cards (up to four) and the controller card.

Apart from the RAM, the RAM board also contains the word recognizer that arranges the triggering of the logic analyser. Via the interface the computer writes into the four registers, IC<sub>13</sub>, IC<sub>16</sub>, IC<sub>24</sub> and IC<sub>27</sub>, the data that determine whether a bit is to be high, low or don't care to trigger the analyser. An XOR-NAND combination is used for each





**Fig. 9. Circuit diagram of the RAM card.**



bit to compare the input data with the set trigger pattern. The individual comparisons are combined into signals ARM and TRIG via the open-collector outputs of the NANDs, which have been linked to form a wired-OR gate. Signals ARM and TRIG are buffered by gates IC<sub>31c</sub> and IC<sub>31d</sub> and then applied to the bus. These gates also have an open-collector output, so that the trigger signals on the bus are again passed through a wired-OR gate, which ensures that the control board receives two complete trigger signals. The XOR-NAND combination and its truth table are shown separately in Fig. 10. The output of this combination must be high for the trigger condition for the relevant bit to be met. When the X input is made low, the output is always high. The bit is then a don't care one in the trigger pattern. When the X input is high, the 0/1 input is used to determine whether the data input must be low or high to meet the trigger condition. The XOR-NAND combinations are connected to the four registers in a manner that ensures that in each of the registers

four 0/1 inputs and four X inputs are juxtaposed.

The printed-circuit board shown in Fig. 11 is straightforward, although some constructors will wonder about the number of wire links. These were found necessary because of the density of the board in a number of places. It was considered that in these instances wire links are safer than copper tracks. Also, they provide a way of keeping the supply to groups of ICs separate, which makes thorough decoupling of the power lines that much simpler. Note that the resistance of the power lines may be made even lower by giving the relevant tracks an extra layer of tin.

Note also the layout of the board around IC<sub>8</sub> and IC<sub>20</sub>. These ICs are normally supplied in widths of 0.3 in., but wider versions are also available. The board is suitable for both types. Whichever type is used, pin 1 must always be inserted into the appropriately marked hole.

(Part 3 will follow in our April 1991 issue)

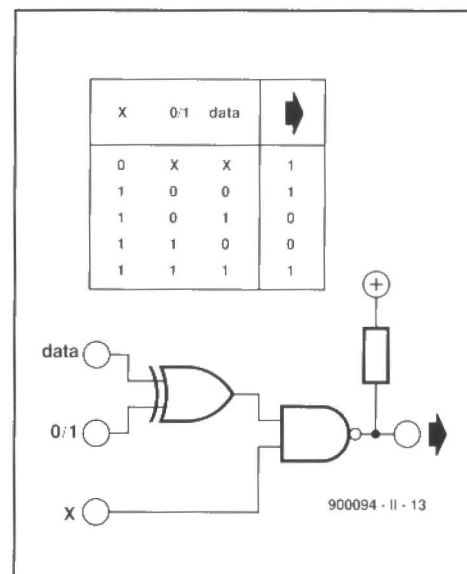


Fig. 10. The word recognizer consists of 16 of the circuits shown here.

#### Resistors:

R<sub>1</sub>, R<sub>2</sub> = 1 kΩ

#### Capacitors:

C<sub>10</sub>–C<sub>31</sub> = 100 nF

C<sub>32</sub> = 100 μF, 25 V

#### Semiconductors:

IC<sub>8</sub>, IC<sub>20</sub> = CY7C128 (6116, 20 ns)

IC<sub>9</sub>, IC<sub>19</sub> = 74HCT245

#### PARTS LIST

IC<sub>10</sub>, IC<sub>21</sub> = 74F574

IC<sub>11</sub>, IC<sub>14</sub>, IC<sub>22</sub>, IC<sub>25</sub> = 74ALS03

IC<sub>12</sub>, IC<sub>15</sub>, IC<sub>23</sub>, IC<sub>26</sub> = 74ALS86

IC<sub>13</sub>, IC<sub>16</sub>, IC<sub>24</sub>, IC<sub>27</sub> = 74HCT574

IC<sub>17</sub>, IC<sub>18</sub>, IC<sub>28</sub>, IC<sub>29</sub> = 74F194

IC<sub>30</sub> = 74HCT138

IC<sub>31</sub> = 74ALS09

#### Miscellaneous:

K<sub>2</sub> = 64-way right-angle male AC connector to DIN 41612

K<sub>3</sub> = 34-way right-angle male header with ejector

PCB Type 900094-2

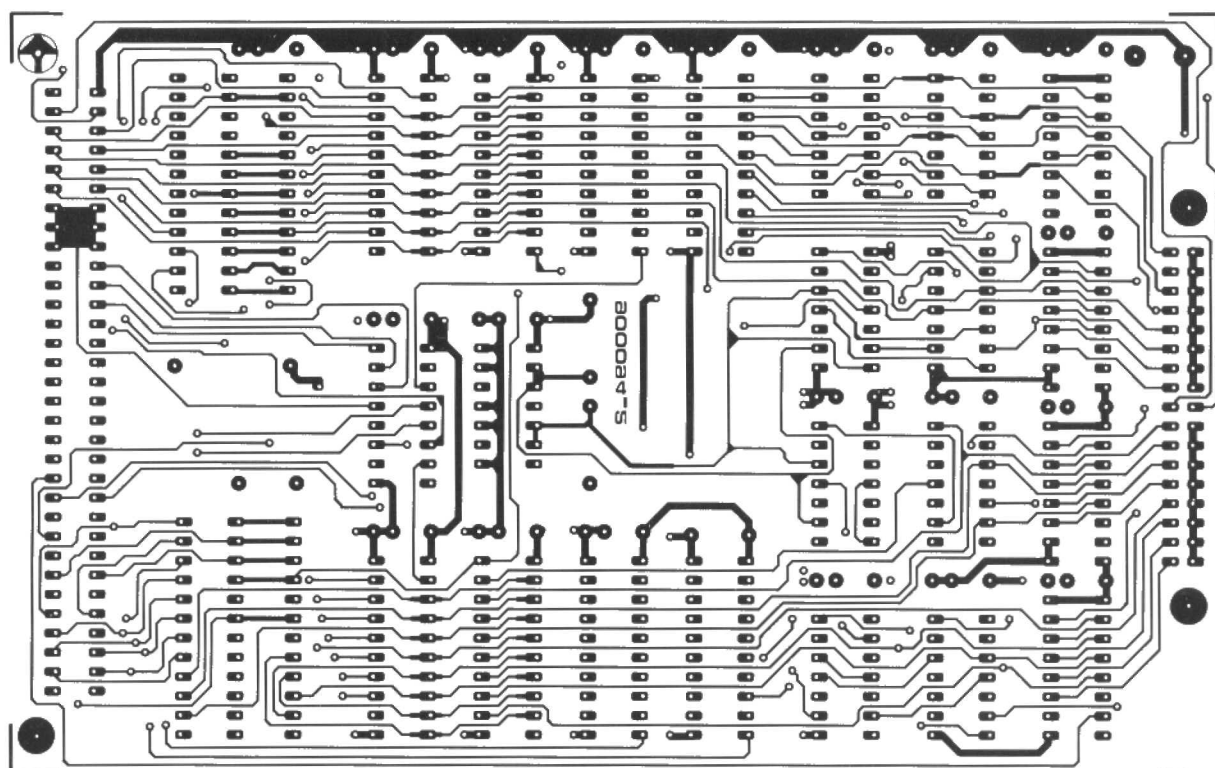
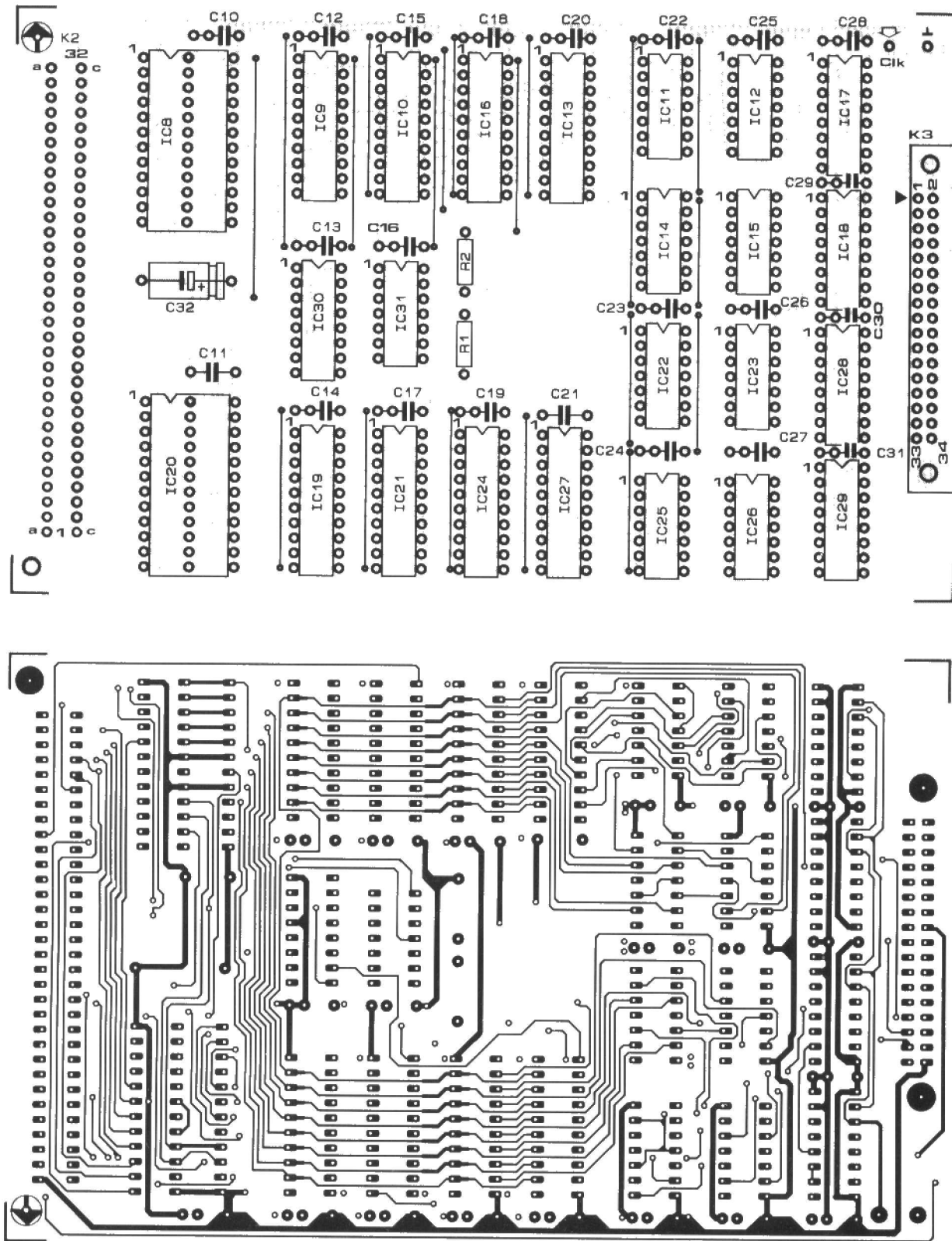


Fig. 11. Printed-circuit board for the RAM card



Register address	Read	Write
0	low byte RAM	trigger nibble 0
1	high byte RAM	trigger nibble 1
2	no address	trigger nibble 2
3	no address	trigger nibble 3

Table 1. Address arrangement for the RAM card.



# OPTICAL-FIBRE COMMUNICATION

Modern telecommunications increasingly uses photonics, the technology of using photons instead of electrons to convey information in a controlled manner. The United Kingdom is a world-leader in this technology and both British Telecom and Mercury Telecommunications already have substantial lengths of optical-fibre cable in everyday use.

THE basic principles of using photons for communication via optical-fibre cable were established by Hockam and Kao, working at the Standard Telecommunication Laboratories at Harlow, Essex, in 1966.

A photon is an elementary particle of light in the frequency range of  $3 \times 10^8$  MHz to  $6 \times 10^{10}$  MHz, corresponding to wavelengths of 1000–5 nm.

A ray of light is the direction along which photons, that is, light energy, travel. A beam of light is a collection of rays. According to the Principle of Reversibility of Light, if a light ray is reversed, it always travels along its original path. Light waves may be refracted or reflected.

In reflection, some or virtually all of the light is thrown back into the original medium when the light strikes the boundary surface between two media. Highly polished metals reflect most of the light incident on them, whereas, for instance, plate glass reflects only about five per cent.

In reflection, the incident ray, the normal, and the reflected ray lie in the same plane. Also, the angle of incidence with the normal is equal to the angle of reflection with the normal—see Fig. 1.

Refraction is the change of direction that a ray of light undergoes when it enters another transparent medium. In refraction, the incident ray, the normal, and the refracted ray lie in the same plane. Snell, a Dutch scientist, found in 1620 that the ratio  $\sin \alpha : \sin \beta$  is a constant, where  $\alpha$  is the angle of incidence and  $\beta$  is the angle of refraction. Snell's Law is usually expressed as

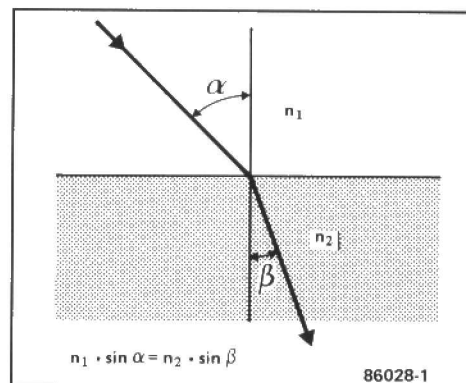


Fig. 2. Illustrating Snell's Law.

$$\sin \alpha / \sin \beta = n_2 / n_1 = \mu, \quad [1]$$

where  $n_1$  and  $n_2$  are the refractive indexes of the two media and  $\mu$  is a constant.

Light is refracted because it has different velocities in different media. The Wave Theory of Light shows that the refractive index  $n_2$  for two given media 1 and 2 is given by

$$n_2 = c_1 / c_2, \quad [2]$$

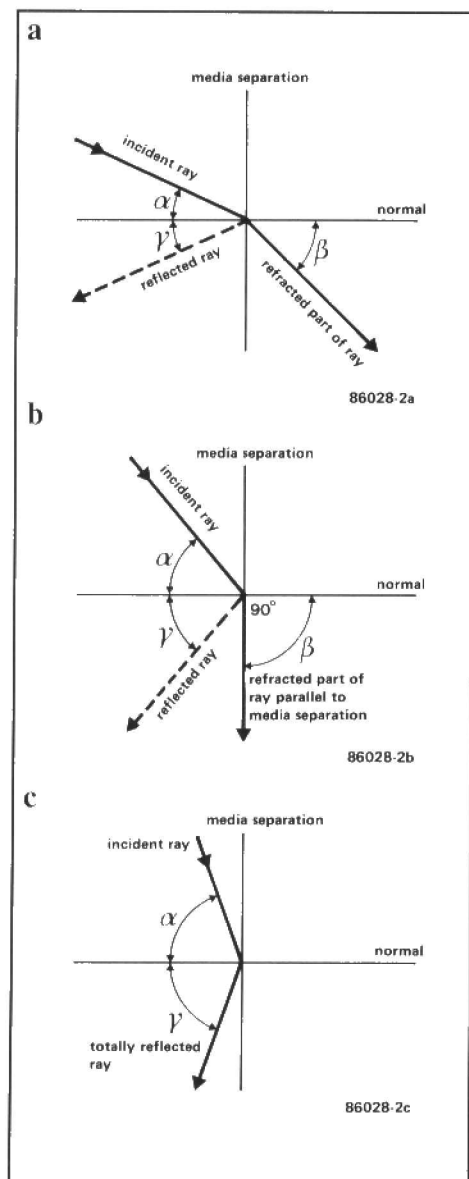


Fig. 1. Depending on the angle of incidence of the light ray, the transmission path is called low- or high-order mode; the greater the angle, the lower the mode.

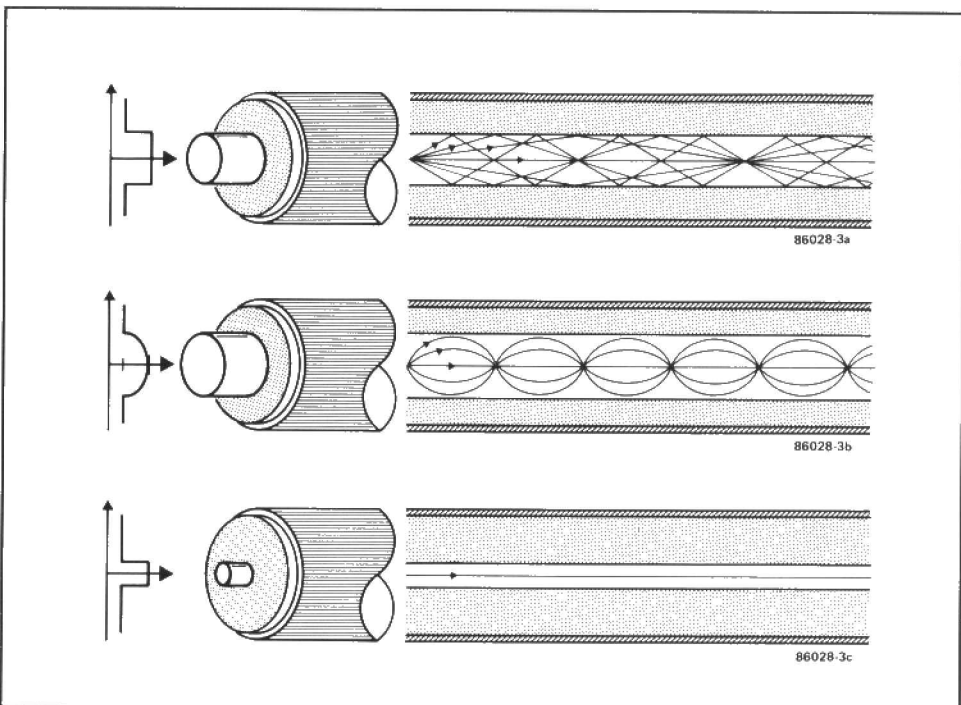


Fig. 3. Top: stepped index multimode cable; centre: graded index multimode cable; bottom: monomode cable. At the left of the drawings are the profiles of the refractive index.

where  $c_1$  and  $c_2$  are the velocities of light in media 1 and 2 respectively.

If medium 1 in [2] is a vacuum, the value is the absolute refractive index. The value for any other two media is the relative refractive index. The absolute refractive index,  $n$ , of a medium is then  $n=c/v$ , where  $c$  is the velocity of light in a vacuum and  $v$  is the velocity of light in the medium. As the absolute index of air is 1.000 29, in practice the velocity of light in air can replace that in vacuum.

There are, of course, situations where there is a partial reflection and a partial refraction of the light. For instance, in Fig. 1a the angle of incidence is so small that a large

part of the incoming light is refracted. In optical fibre, this would mean that a large part of the light would be lost in the cladding of the cable. Figure 1b shows the critical angle of incidence: the refracted light here is at an angle of  $90^\circ$  with the normal. At the critical angle, the refracted light may cause interference. It is, therefore, essential that the angle of incidence is greater than the critical angle—see Fig. 1c—when total reflection takes place. Note that the angle of incidence,  $\alpha$ , is equal to the angle of reflection,  $\gamma$ . The condition for total reflection is that the ray of light travels from an optically dense medium with a relatively large refractive index to a less dense one with a smaller refractive index.

Rays of light that fall upon the media boundary at an angle smaller than the critical angle are called high-order modes: they take relatively longer to reach the end of the cable. Rays of light that travel almost parallel to the optical axis, that is, at an angle greater than the critical, are called low-order modes. Low-order modes travel faster because they are reflected less often than high-order modes. Low-order modes are far less prone to losses than high-order ones.

The sine of the angle of incidence of the ray of light is called the numerical aperture: this is the prime factor where two optical waveguides are to be linked. The numerical aperture is also an indication of the difference

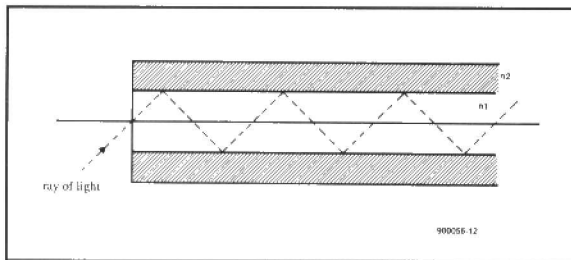


Fig. 4. Longitudinal cross-section of an optical fibre cable. The refractive index of the core is slightly higher than that of the cladding.

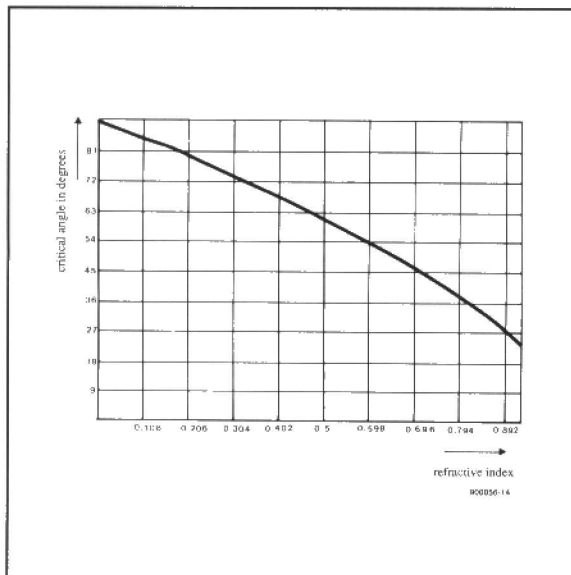


Fig. 6. Relationship between the critical angle and the refractive index  $n_2$  with  $n_1$  given a value of 1.

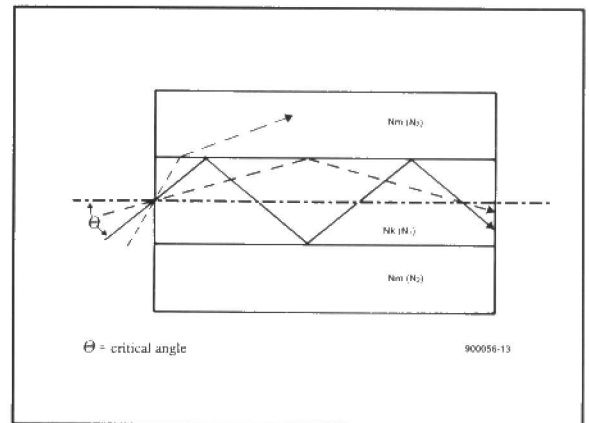


Fig. 5. If the ray of light is input at an angle greater than the critical angle  $\theta$ , it is not reflected internally but absorbed in the cladding.

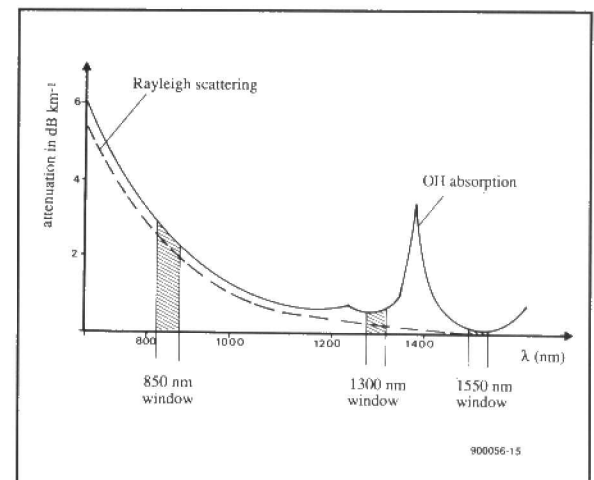


Fig. 7. Relationship between attenuation presented by an optical-fibre cable and the wavelength of the input light.

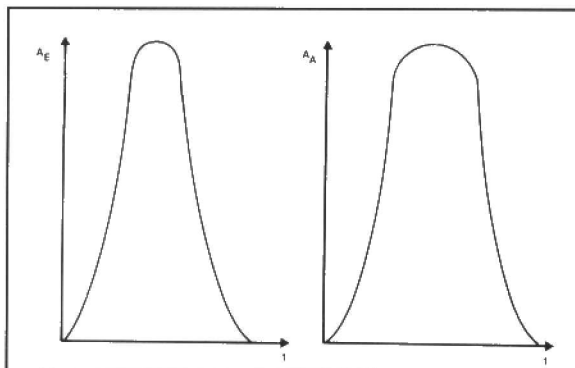


Fig. 8. Dispersion causes the width of the light pulses to be increased.

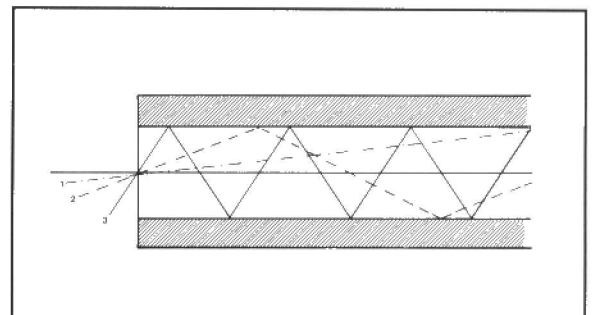


Fig. 9. Depending on the input angle, different rays of light travel different distances, and this causes their transit times to be of different duration.



between the refractive indexes of the core and the cladding: the smaller it is, the greater the bandwidth of the optical signal.

In mono-mode (also called single-mode) optical-fibre cables (Fig. 3) the core diameter is comparable to the wavelength of the light, so that there can be only one electromagnetic mode of propagation and spreading of the pulse, called multi-path dispersion, is eliminated.

In multi-mode optical fibre cables—see Fig. 3—the ray paths of the different modes are of different lengths and have, therefore, difference transmission times. Because the modes are divided by a pulse, this is subject to progressive spreading as it travels along the fibre, causing it to interfere with adjacent pulses.

Its small core size makes mono-mode fibre more difficult to use, but it has a smaller attenuation than multi-mode fibre cables.

Optical fibre cable in practical use consists of a light-conductive cylindrical core of doped silica clad in pure silica—see Fig. 4. The refractive index,  $n_2$ , of the cladding is

about 1% smaller than that of the core,  $n_1$ . This makes total internal reflection possible at the boundary between core and cladding of all rays of light that enter the cable at an angle smaller than the critical (Fig. 5). The critical angle,  $\theta$ , is

$$\theta = \arcsin \sqrt{n_1^2 - n_2^2},$$

and it depends therefore only on the refractive indexes  $n_1$  and  $n_2$ . If  $n_1 = 1$  (vacuum) the characteristic curve in Fig. 6 pertains. Often, the numerical aperture, NA, is given instead of the critical angle:

$$NA = \sin \theta = \sqrt{n_1^2 - n_2^2}.$$

## Cable characteristics

The transient response of an optical-fibre cable depends, apart from its geometrical characteristics pertaining to the core and cladding, on its optical attenuation and scattering. The attenuation is largely dependent on the wavelength of the input light. It consists of

two components: one caused by absorption and the other by dispersion.

The absorption component is specific to the glass fibres and can be kept to a minimum during manufacture, when, for example, oxygen-hydrogen (OH) ions may get trapped in the material. Such impurities absorb light at a number of wavelengths as shown in Fig. 7. Note that the attenuation of wavelengths around 1300 nm and 1150 nm is very small.

The dispersion component depends on the properties of the cable. It manifests itself as a variation of refractive index with the wavelength of the light.

Some spurious particles will always be present in the glass; they come about during the melting process. The dispersion caused by these particles, which are small compared to the wavelength of the light used, is called Rayleigh scattering, which reduces with increasing wavelength—Fig. 7. Scattering is an intrinsic property of the glass; it cannot be eliminated. It is partly caused by the glass fibres and partly by properties of the

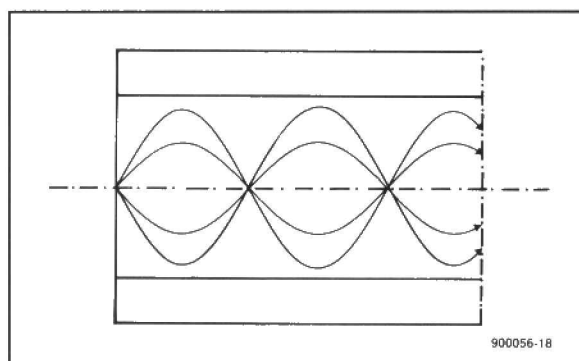


Fig. 10. Because of the continuously varying refractive index of graded index optical-fibre cables, rays of light in these cables travel along helical instead of linear paths.

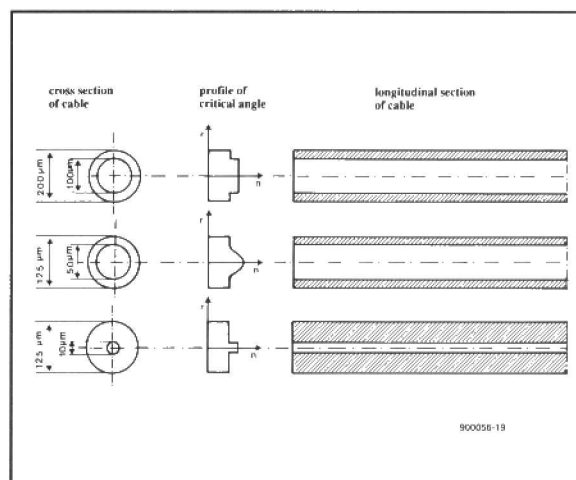


Fig. 11. Diagrammatic representation of the three types of optical-fibre cable. That at the top, a stepped index mode type, is virtually out of production.

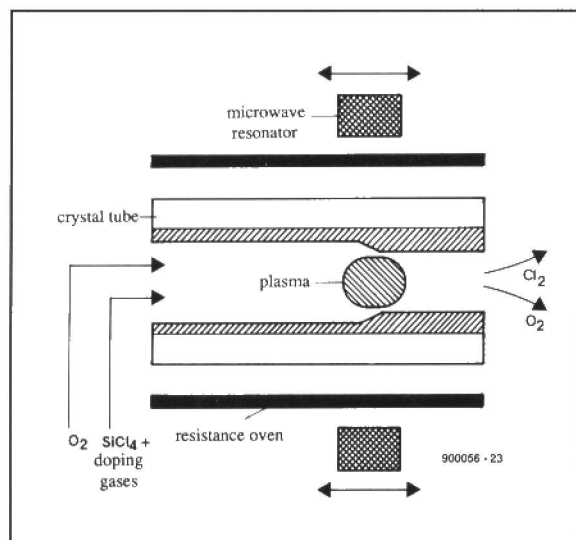


Fig. 12. Simplified diagram of production set-up.

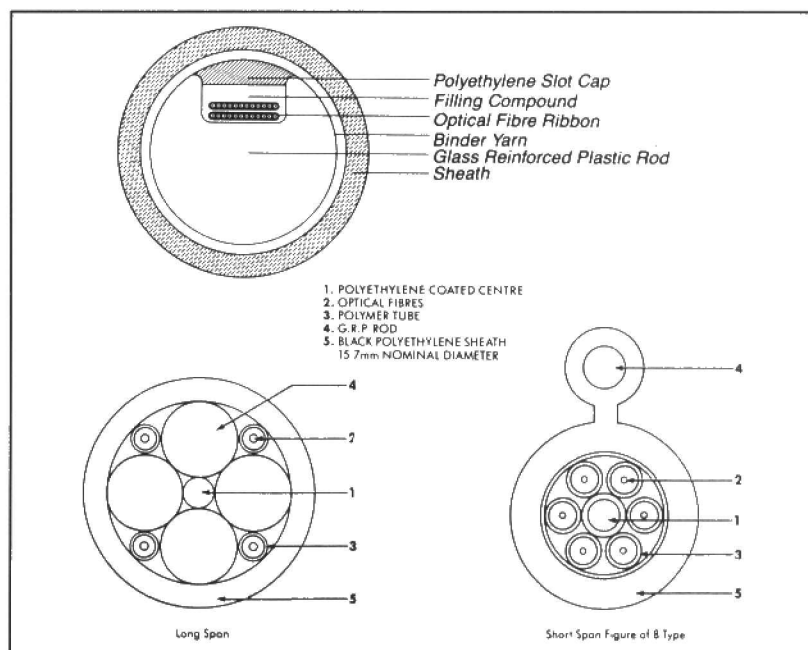


Fig. 13. Some multi-core optical-fibre cables: top: Fibrespan (made by STC) and below: Translite (made by TCL, a subsidiary of General Electric).

light input.

Dispersion results in an increase in pulse width of the light during its travel through the cable (see Fig. 8). The increase is proportional to the distance between sender and receiver, that is, the length of the cable. It is normally given in picoseconds per kilometre ( $\text{ps km}^{-1}$ ).

Mode scattering is caused by the various light rays entering the cable at slightly different angles—see Fig. 9. It is clear that different rays travel different distances through the cable and this leads to attenuation of the input signal. The difference between the shortest and longest transit times,  $\Delta t$ , is

$$\Delta t = n_k(n_k n_m) / cn_m,$$

where  $n_k$  is the refractive index of the core material,  $n_m$  the refractive index of the cladding and  $c$  the speed of light.

The smaller the dispersion attenuation of an optical-fibre cable, the larger the trans-

mission bandwidth. In practice, the bandwidth,  $B$ , is  $B = 0.44/T$ , with  $T$  determined at the  $-3$  dB pulse amplitude.

## Practical cables

A multimode cable is one with a core diameter sufficiently larger than the wavelength of light to allow propagation of light energy in a large number of different modes. Multimode cables embrace stepped index and graded index types. Stepped index types have a core whose refractive index is constantly higher than that of the cladding, that is, the index changes abruptly at the boundary of core and cladding. Owing to mode dispersion, the attainable bandwidth of this type of cable is limited to about  $100 \text{ MHz km}^{-1}$ .

The refractive index of the core of graded index cables reduces parabolically by 1% from the centre of the core to that of the cladding. This results in the light rays travelling along helical instead of linear paths in the cable—see Fig. 10. This results in a noticeable reduction in transit times and dispersion attenuation. Dispersion attenuation values of  $0.2 \text{ ns km}^{-1}$  and corresponding bandwidths of  $1 \text{ GHz km}^{-1}$  are attainable.

The graded index cable has become an international (CCITT) standard with a core diameter of  $50 \mu\text{m}$ , a cladding diameter of  $125 \mu\text{m}$ , and a numerical aperture of 0.2 (Fig. 11).

A monomode cable is a stepped index type whose inner core diameter (of higher refractive index) is comparable with the wavelength of light; this results in there being only one mode of light propagation. Mode dispersion is thus eliminated. Monomode cables do not cause transit delays, which results in very large bandwidths of more than  $10 \text{ GHz km}^{-1}$ . Since the attenuation of these cables is also small, they are eminently suitable for wide-band and long-distance communication.

Diagrammatic representa-

tions of the three types of cable are shown in Fig. 11. The most commonly used is the graded-index type. The transfer capacity of this type of cable is normally greater than required. Moreover, the in- and out-coupling of light is easier with this cable than with the mono-mode type. The attenuation of commercially available graded-index cable is  $5\text{--}10 \text{ dB km}^{-1}$ , which is not a lot worse than that of mono-mode cable. On the other hand, the dispersion in mono-mode cable is much smaller than in multi-mode cable. Owing to its high attenuation of  $10\text{--}30 \text{ dB km}^{-1}$  and its smaller transfer capacity, the stepped index multimode type of cable is now virtually out of production.

## Cable manufacture

Glass fibres are normally manufactured by the plasma activated chemical vapour deposition (PCVD) technology. In this, a mixture of silicon chloride, germanium chloride and oxygen is passed through a very pure quartz tube. This gas mixture causes a plasma reaction zone in the field of a microwave generator, which results in the deposition of a doped quartz layer ( $\text{SiO}_2$ ) at the internal surface of the tube (see Fig. 12). By axially shifting the microwave generator along the tube, an even thin layer is deposited. The core is built up of some hundreds of such layers. By varying the Ge doping of individual layers it is possible to obtain a very exact refractive index profile, which is a prerequisite for large transmission bandwidths.

The quartz tube is then heated to a temperature where it collapses into a solid  $1.5 \text{ m}$  long glass rod. This rod is then heated to near its melting point and drawn into a fibre some  $15 \text{ km}$  long with a diameter of  $125 \mu\text{m}$ . To prevent damage to this fragile strand, it is immediately given a primary coating of man-made fibre. Later, a secondary coating of man-made fibre is applied to give it the tensile and mechanical strength required for processing it into a cable. The protective sheathing of the cable does not affect the optical properties. Over the past few years, multi-core optical-fibre cables as shown in Fig. 13 have become available, which have opened up enormous possibilities for improving and expanding communications systems.

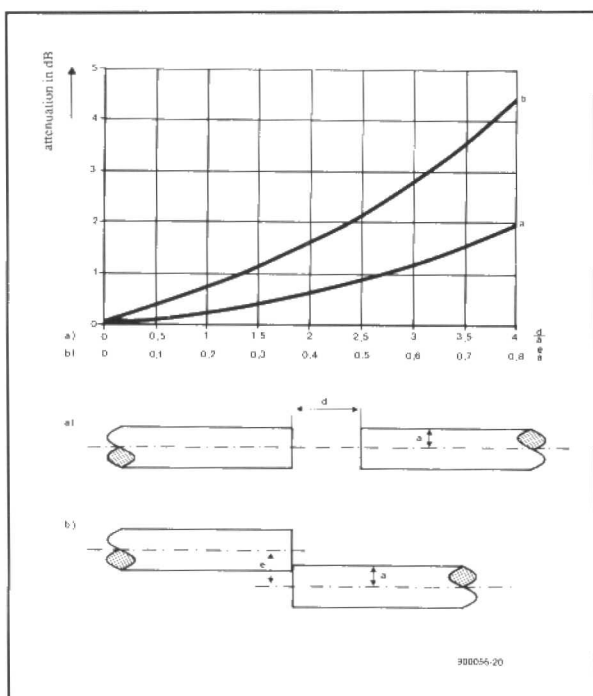


Fig. 14. Attenuation as function of (a) the distance between the cable ends, and (b) radial displacement between the cores.

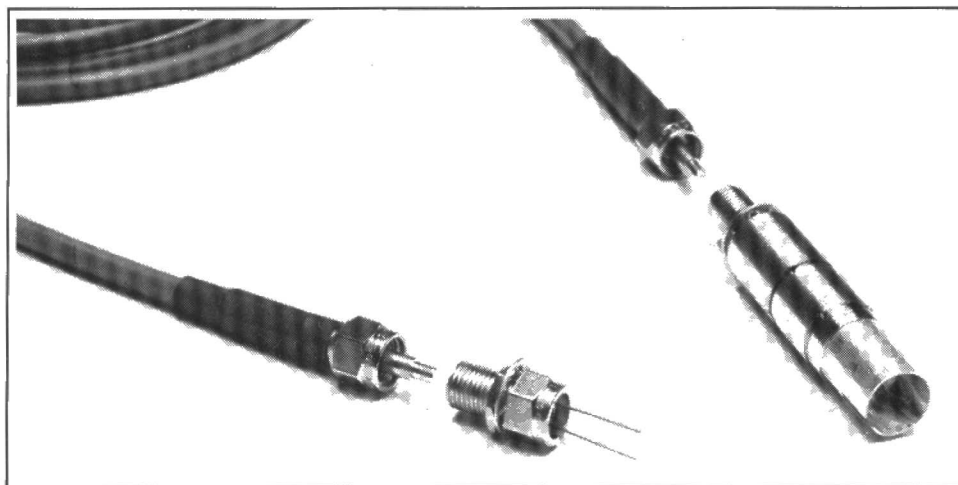


Fig. 15. Some commercially available couplers for use with optical-fibre cable.

## Coupling techniques

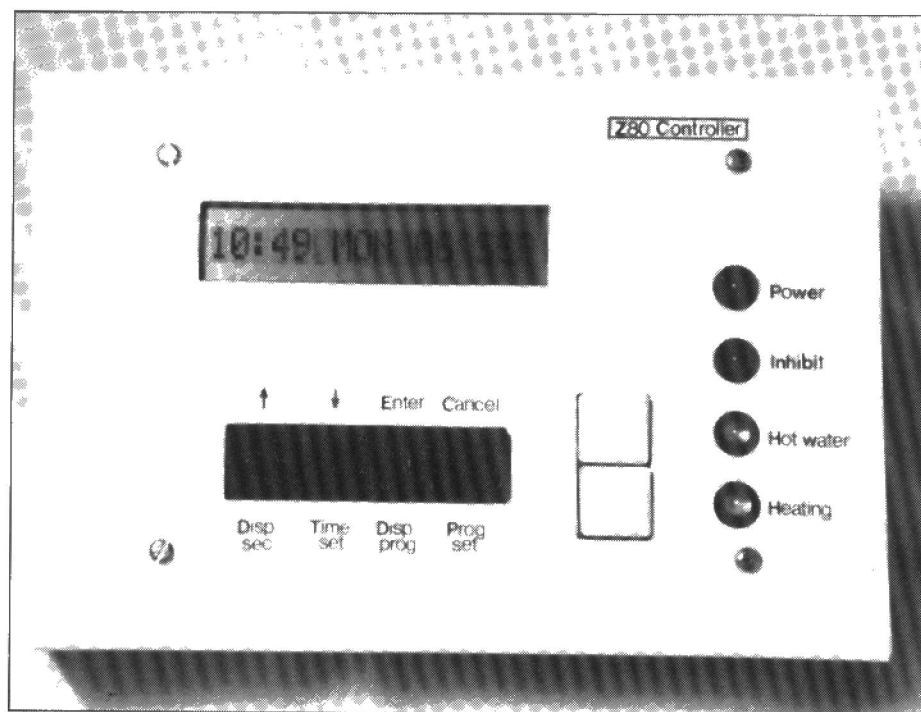
Couplers are, of course, required for connecting the optical fibre cables to transmitters, receivers and repeaters, although cables may also be lengthened by splicing. Whether a coupler or a spliced joint is used, additional attenuation is the result, which depends on the distance between the cable ends, and the radial as well as the angular displacement between the two cores. In a spliced joint the cable ends are fused and this type of coupling therefore gives the lower attenuation as shown by curve *a* in Fig. 14. In many cases, however, removable connections are required and for these there are now a number of optical couplers available commercially (see Fig. 15).

# CENTRAL HEATING CONTROLLER

## PART 1: SYSTEM OUTLINE AND CIRCUIT DESCRIPTION

Most householders these days employ timeswitches to control their central heating systems. Many of these switches, however, are of the mechanical type, with a limited number of switching steps, and with no facilities to vary the program from one day to the next. It is only fairly recently that electronic controllers have appeared on the scene, and the one described here is designed to give a wide range of programming options, which can easily be changed.

K. Browne



### MAIN FEATURES

- Microprocessor-controlled
- Programs can be selected on an individual day, weekdays only, weekend only, or on an every day basis
- One-shot or repeating programs
- Separate control of heating and hot water systems
- Override and inhibit functions
- Battery backup in the event of power failure

The key switches and display unit are mounted on a separate PCB. The 6 keys interface with the data bus via diodes, and perform multiple functions to enable the user to program the timeswitch.

The display unit is a 1-line, 16-character LCD (liquid crystal display) module from Seiko-Epson. The unit contains its own ROM character generator and display RAM. Care should be taken when handling the LCD as it is quite expensive and easily damaged.

**T**HE block diagram of the system is shown in Fig. 1. The CPU (central processing unit) is a CMOS version of the popular Z80 8-bit microprocessor. This is connected to the ROM (read-only memory), RAM (random-access memory), display unit, key switches and output latch via a common 8-bit data bus.

The ROM contains the control program, enabling the CPU to perform the timeswitch operations. This IC is a CMOS version of the perhaps more common 2764 8K×8 bit EPROM. The control program would actually fit in the smaller 2732 4K×8 bit EPROM. At the time of writing, however, the 2732 was not available in a CMOS version at a reasonable price.

The RAM is a 2-Kbyte CMOS memory

chip, which is used to store the switching program, the current time and other system variables.

Two bits of the output latch are used to control the switching relays. A further three bits control LED indicators on the front panel.

A mains-derived 50 Hz signal is provided for the CPU by the timing section of the circuit. This signal is required for timekeeping purposes.

The power supply provides a stabilized 5 V rail for all the circuits. This supply is either derived from the mains, or, in the event of a mains failure, from a stand-by battery source. The battery can be of the rechargeable type, since the PSU also supplies a charging current.

### The circuit details

#### Power supply section (Fig. 2)

Transformer Tr1 reduces the mains voltage to 12 V, which is rectified by diodes D1 to D4, and smoothed by capacitor C2 to provide approximately 12 VDC. This voltage is used, via resistor R6 and diode D8, to charge the stand-by battery, if required. The 12-V supply is also fed, via D7, to a 5-V fixed voltage regulator, IC2.

Resistor R1 feeds the positive half-cycles of the mains frequency to an optocoupler, IC1, whose output drives a pulse-shaping circuit formed by C1-R3. The resulting short-duration positive pulses are inverted by IC3E, and subsequently used as a reference



by the CPU to synchronize the timekeeping function. Transistor T1, diode D6 and resistor R5 form a monitor circuit for the 12-V supply. T1 is normally on. In the event of a mains failure, R4 discharges smoothing capacitor C2. When the voltage across C2 falls to about 8 V, T1 is turned off, providing a power fail signal to the rest of the circuit.

#### The timing section (Fig. 3)

As previously mentioned, the CPU requires a timing or interrupt signal of 50 Hz. The normal supply of this signal is from IC3F in the power supply circuit. The pulses are applied to the interrupt input of the CPU. To prevent the system losing its timing reference when the mains fails, a second source of 50 Hz pulses is implemented in the form of an oscillator circuit based on IC9. The frequency of oscillation is set by resistors R12, R13 and capacitor C7. Preset P13 allows fine tuning of the frequency to exactly 50 Hz. The power fail indication from T1 in the PSU circuit is connected to the oscillator circuit by diode D9. The result is that IC9 provides an output signal only when a mains failure occurs.

#### The CPU circuit (Fig. 4)

A clock supply for the CPU is generated by the circuit around IC3C. The quartz crystal in

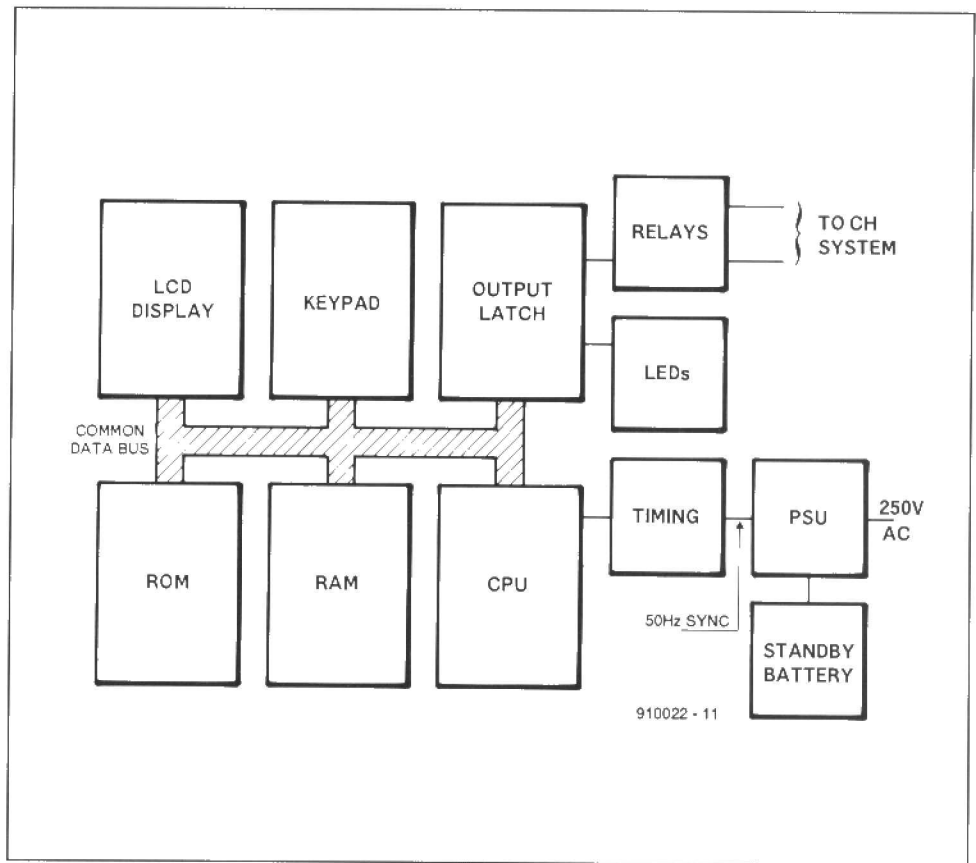


Fig. 1. Block diagram of the Z84C00-based central heating controller.

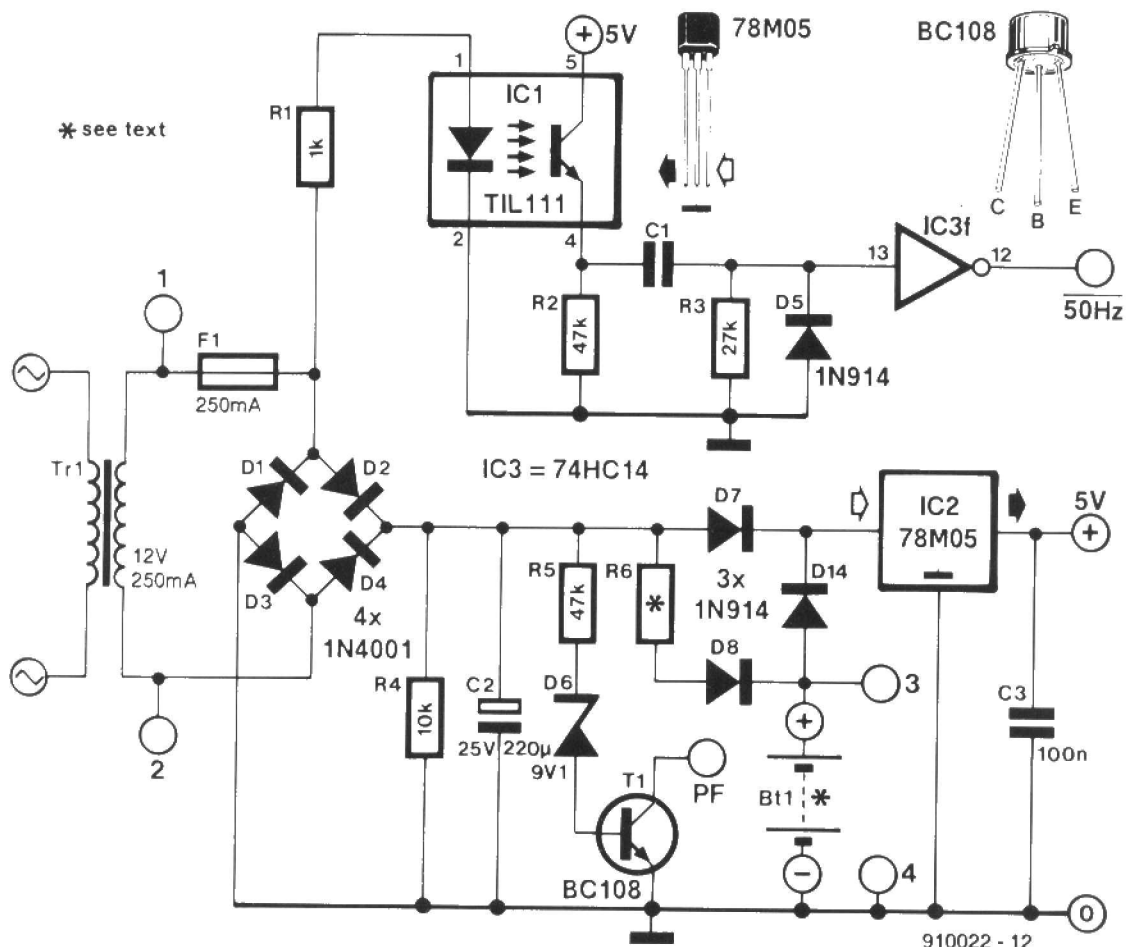


Fig. 2. Circuit diagram of the power supply and the 50 Hz timebase, which derives its accuracy from the mains.

this circuit is a 2-MHz type. A lower frequency than the maximum specification of the CPU is used in view of the LCD unit, which can only operate with signals up to 3 MHz. The 8-bit data bus is connected to the ROM, IC<sub>5</sub>, the RAM, IC<sub>6</sub>, and the output latch, IC<sub>7</sub>. Twelve of the address lines, A0 to A11, are also connected both to the ROM and the RAM ICs. The remaining address lines, A12 to A15, are used to select various ICs connected to the data bus. A number of gates in IC<sub>8</sub> 'AND' these address lines with the MRQ (memory request) output from the CPU, to provide the correct timing. A truth table of the address decoding logic is shown in Table 1.

### Display module and key switches (Fig. 5)

The 8-bit data bus from the CPU, along with two of the address lines, A0 and A1, is extended through to the display PCB. The six key switches, SW20 to SW25, are connected direct to individual lines of the data bus. Pressing a key, however, has no effect unless the  $\overline{\text{IORQ}}$  (input/output request) line of the CPU is low. This terminal is normally high, and only taken low when the CPU requires to read the key switches. It does this periodically under software control. When a key is pressed during a CPU read cycle, the appropriate data line is pulled low via one of the diodes D20 to D25. If two or more switches are pressed at the same time, this prob-

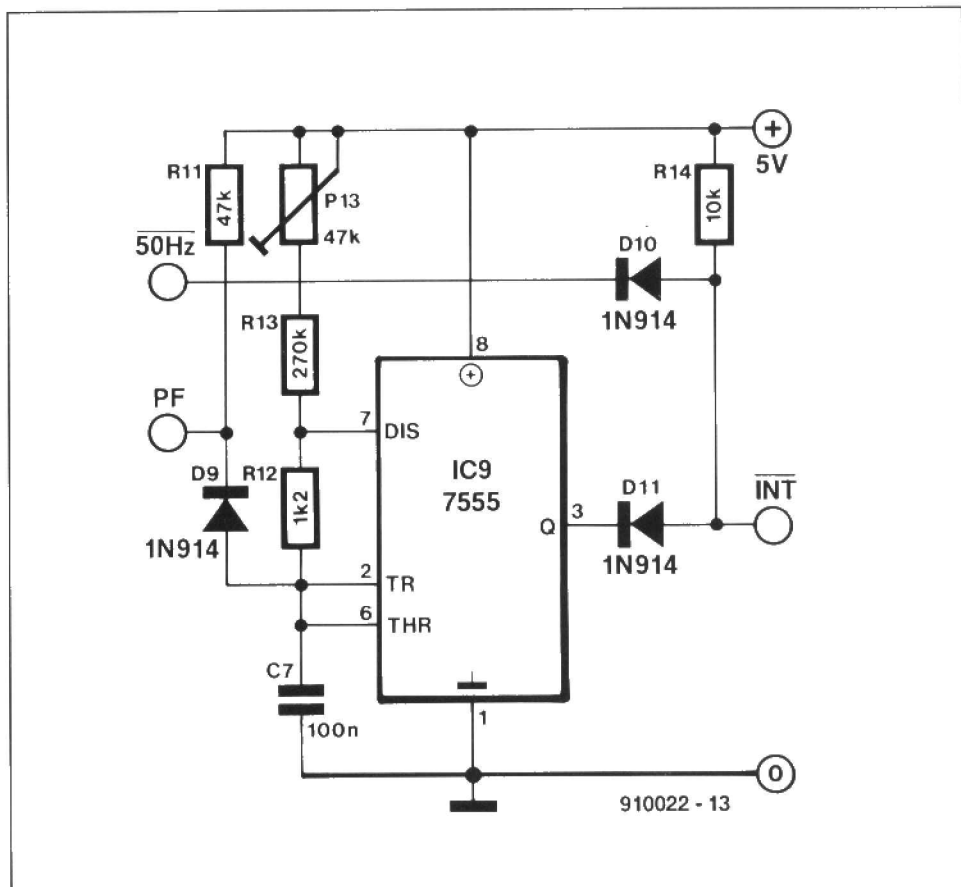


Fig. 3. Circuit diagram of the mains-synchronized timebase. The interrupt pulses supplied by this circuit are fed to the microprocessor.

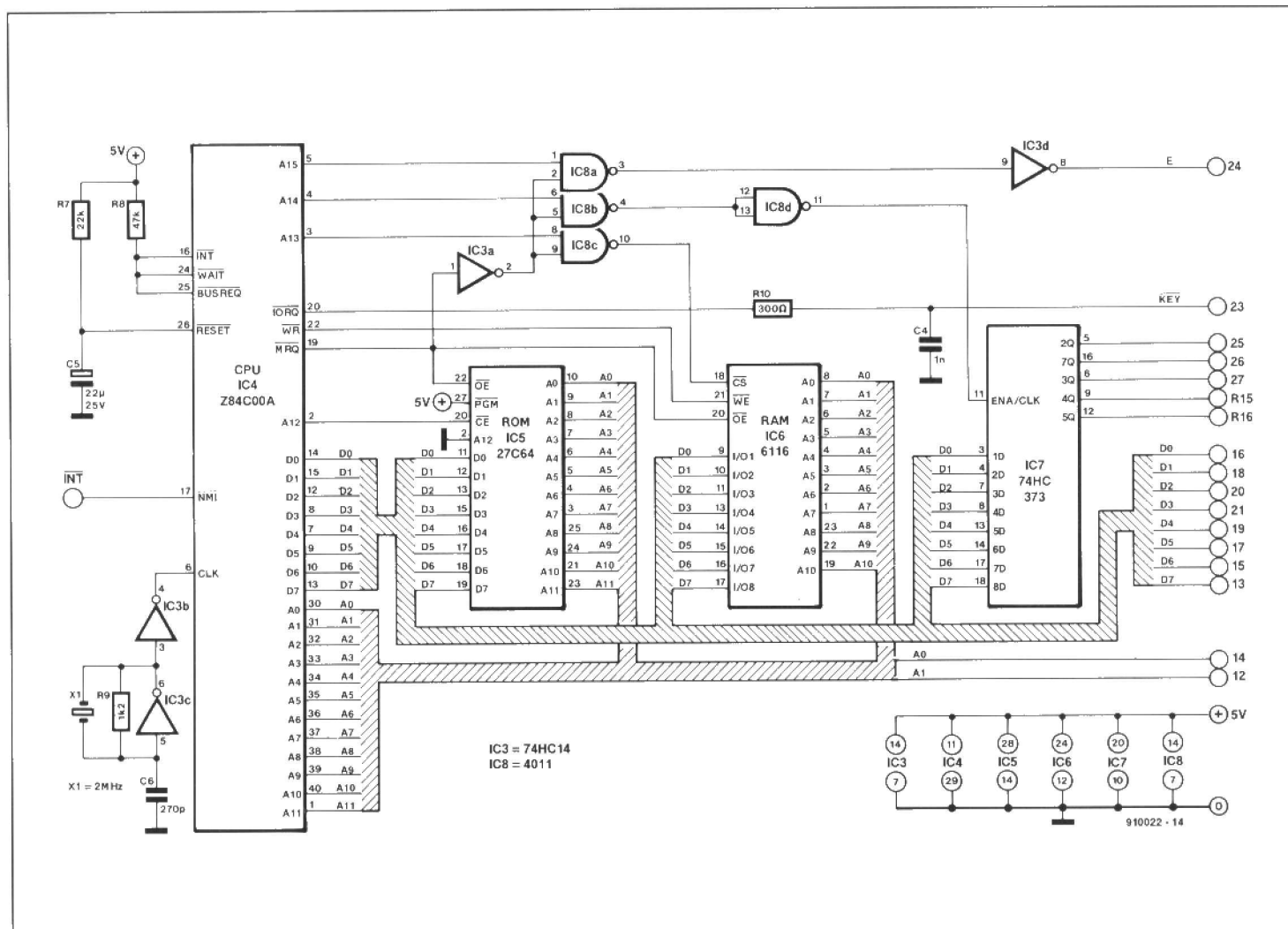


Fig. 4. The heart of the controller is formed by a computer system based on Zilog's Z84C00 8-bit CMOS microprocessor.

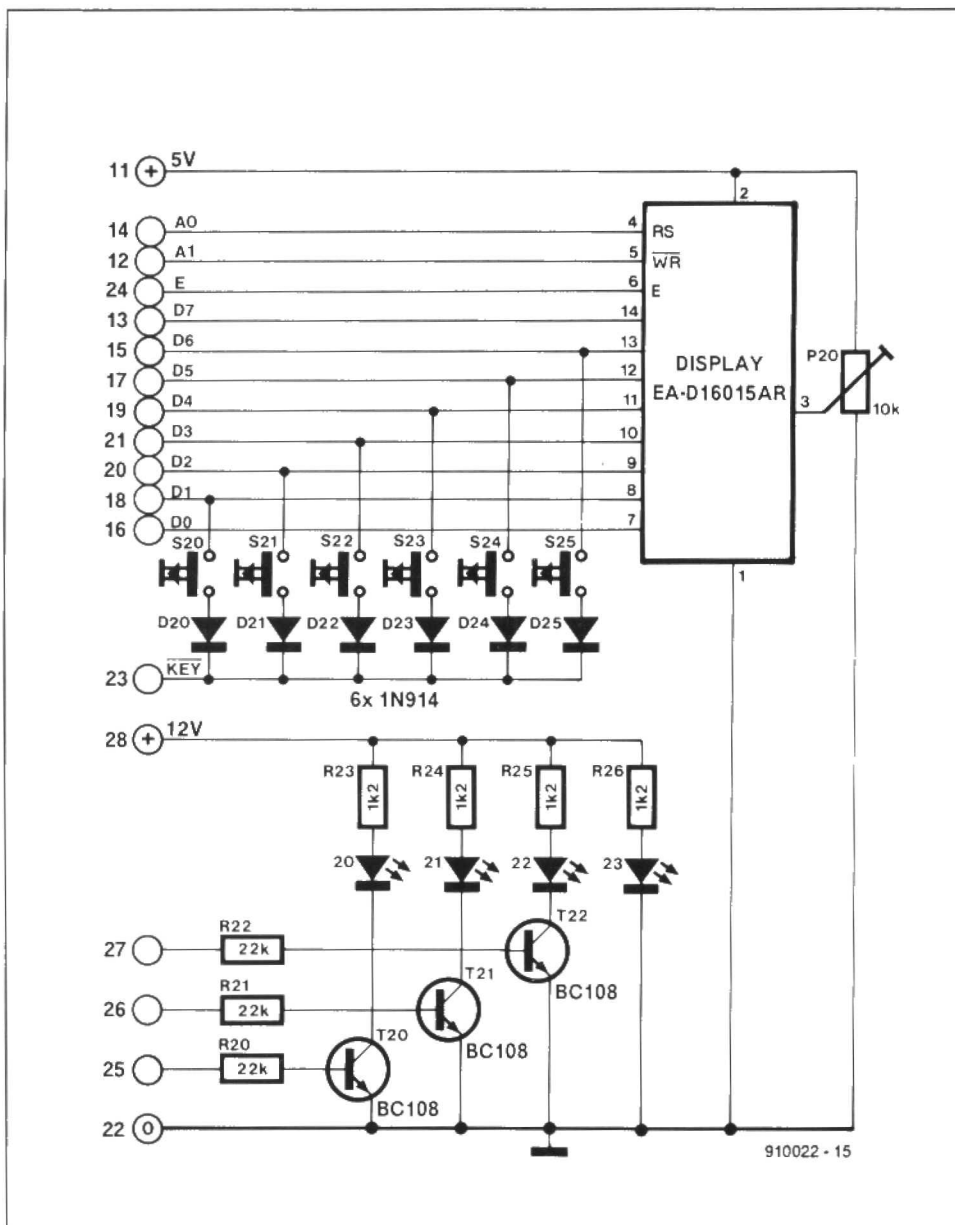


Fig. 5. The display circuit of the CH controller is based on an intelligent LCD module from Seiko-Epson.

CPU/Address lines					IC selected	Base address (hex)
MRQ	A15	A14	A13	A12		
0	0	0	0	0	ROM	0000
0	0	0	1	1	RAM	3000
0	0	1	0	1	Output latch	5000
0	1	0	0	1	Display module	9000

Table 1. Address decoding in the microprocessor system.

CPU/Address lines							Address (hex)	Display module register selected
MRQ	A15	A14	A13	A12	A1	A0		
0	1	0	0	1	0	0	9000	Instruction Register (write)
0	1	0	0	1	0	1	9001	Data Register (write)
0	1	0	0	1	1	0	9002	Instruction Register (read)
0	1	0	0	1	1	1	9003	Data Register (read)

Table 2. Display module register selection.

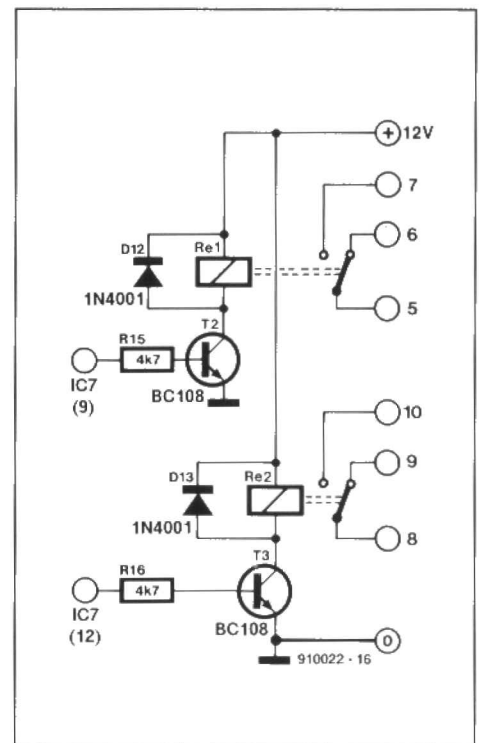


Fig. 6. The relay driver circuit that forms the link between the controller and the CH pumps, valves and the boiler.

lem is sorted out by the software.

The display module proper is self-contained. The CPU writes data to, or reads data from, either the control or the data registers in the display module. Access to the registers is controlled by the two lower address lines, A0 and A1, and by address line A15 (see Table 2). A summary of the control codes and character set available in the display module is detailed in Table 3.

Preset P20 is provided to adjust the contrast of the display. Four LEDs are also accommodated on the display PCB. LED20 and LED21 indicate the state of the 'hot water' and the 'heating system' respectively. LED22 is used to indicate the state of the inhibit control. These three LEDs are controlled by the CPU via the output latch and driver transistors T20, T21 and T22. LED23 indicates that mains power is present to the unit.

#### Relay section (Fig. 6)

Two changeover relays, RL1 and RL2, control the actual central heating system. They are operated by the CPU via the output latch and the drivers, T2 and T3.

*Continued next month.*



# INTERMEDIATE PROJECT

**A series of projects for the not-so-experienced constructor. Although each article will describe in detail the operation, use, construction and, where relevant, the underlying theory of the project, constructors will, none the less, require an elementary knowledge of electronic engineering. Each project in the series will be based on inexpensive and commonly available parts.**

## SIMPLE FUNCTION GENERATOR

**The test instrument presented here is capable of supplying sine-wave, square-wave and triangular-wave signals with an adjustable amplitude of 0 to 12 V. The square-wave output in addition offers a fixed 5-V level for easy use with digital circuits. The frequency range of the generator is 2 Hz to 25 kHz.**

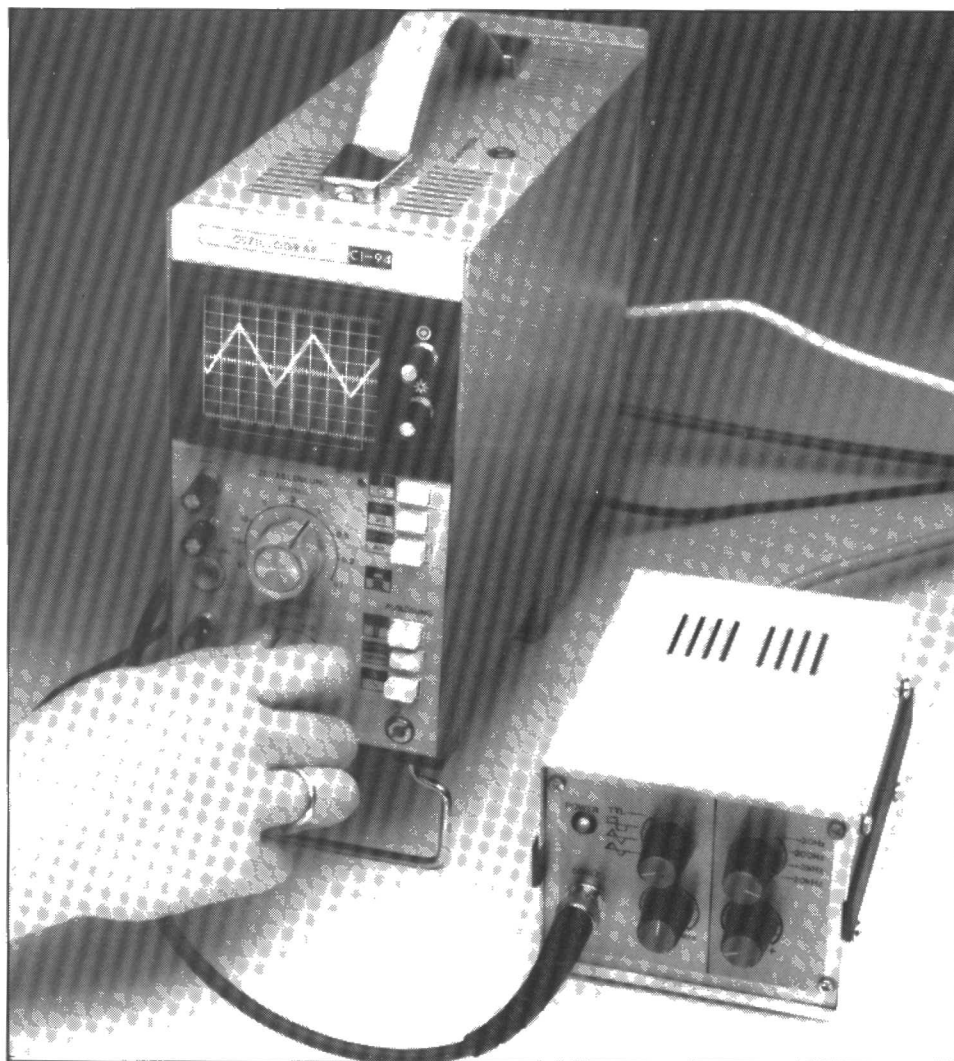
**D. Harkema**

**I**F you are into testing and designing electronic circuits at almost any level, a function generator and an oscilloscope are indispensable instruments on the work bench. Sine-wave signals produced by a function generator are typically used to check the frequency response and power output of audio amplifiers, and to align filters. The triangular waveform, often mistakenly referred to as 'ramp' or 'sawtooth', enables you to measure the cross-over distortion of a balanced amplifier. The square-wave output has the widest application range: it is generally used for overshoot, frequency response and pulse response measurements on audio amplifiers. Applied to digital circuits, the square-wave function is often used to provide a variable clock generator. For this purpose, the generator output level is either 5 V for TTL circuits, or 12 V (generally) for CMOS circuits. In any case, make sure you know the supply voltage of the digital circuit connected to the generator, and the required drive level of the logic ICs.

### Integrator

To help you in locating the individual circuits that together form the function generator, and understanding the basic function of each of these circuits, the simplified schematics are first discussed with reference to Fig. 1. For convenience, the part reference numbers in the simplified schematics correspond to those in the full circuit diagram, discussed further on.

The first sub-circuit is an integrator (Fig. 1a). When a constant voltage is applied



to the input, capacitor  $C_1$  is charged with a constant current. Hence, the voltage across  $C_1$  rises, in principle, linearly as a function of time, and not according to a logarithmic function ( $e$ -curve) as in a resistor-based charging circuit. The opamp is responsible for this linearization of the charge voltage. Since the inverting input of the opamp forms a virtual ground, all input current is, in principle, sent into the capacitor. This means that the capacitor charge current is equal to the current that flows through the input resistor. This current is simple to calculate since the value of the resistor is known, and the voltage across the resistor equals the input voltage. In the present circuit, there are only two voltage levels, 'high' and 'low'. You have guessed it: the integrator is driven by a square-wave signal.

The capacitor is charged by the 'high' voltage level, and discharged by the 'low' voltage level. Because of the integrating operation of the capacitor, its right-hand terminal supplies a triangular voltage, which corresponds to the charge voltage (remember that the left-hand terminal of the capacitor is at 'virtual' ground). If you want to demonstrate the operation of the integrator, use a large time constant by fitting a capacitor of say,  $1\ \mu\text{F}$ , for  $C_1$ , and a resistor of  $1\ \text{M}\Omega$  at the opamp input. These component values make the integrator so slow that a simple multimeter connected to the output will clearly indicate a slowly rising and falling voltage when the input is taken low and high (in that order because of the inverting function of the opamp).

## Schmitt trigger

The previously mentioned square-wave signal that drives the integrator is supplied by an oscillator based on a Schmitt-trigger. The basic schematic of this circuit is given in Fig. 1b. Like the integrator, the Schmitt-trigger is based on an operational amplifier. Resistor junction  $R_{12}$ - $R_{13}$  is connected to the non-inverting opamp input and causes positive feedback instead of negative feedback as with the integrator. Contrary to a 'normal' circuit with positive feedback, however, the Schmitt-trigger sees its output voltage reach the full positive and negative supply level. When the input voltage is sufficiently positive, the output voltage reaches the positive supply level. When a negative input voltage is applied, the opamp output voltage is nought. The feedback resistor between the input and the output of the opamp also enables the circuit to settle in one of two stable states, like a flip-flop. The opamp can be made to change state by applying a sufficiently high reverse voltage to the +input. This happens when the voltage at the resistor junction exceeds that at the inverting input of the opamp. Hence, there is a certain degree of hysteresis. If we apply a sine-wave to the circuit, the output will not go high until the instantaneous amplitude of the input signal is a little higher than  $0\ \text{V}$ . Similarly, the output goes low when the input signal is a little below  $0\ \text{V}$ . The upshot is that

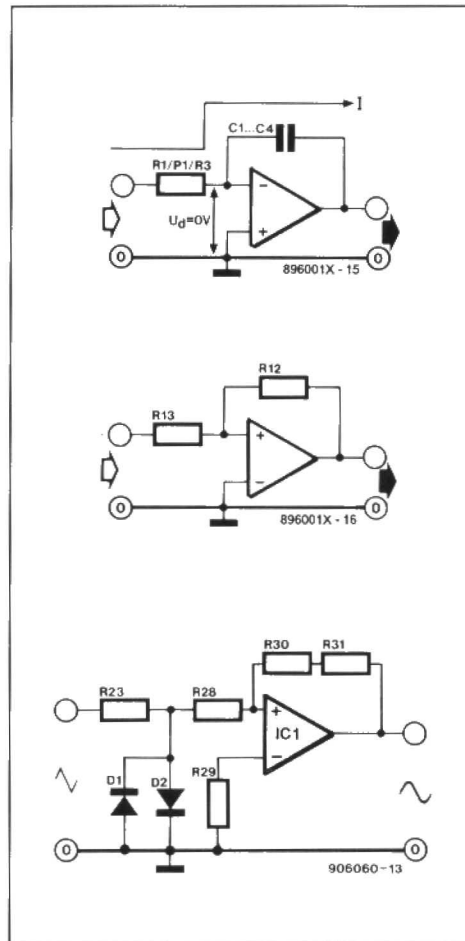


Fig. 1. The main sections of the circuit are formed by an integrator (Fig. 1a), a Schmitt-trigger (Fig. 1b), and a sine-wave shaper (Fig. 1c).

the circuit in Fig. 1b converts a sine-wave into a square-wave.

## Generator

A signal generator is created by combining the circuits in Fig. 1a and Fig. 1b. In principle, all that is required is to connect the output of one circuit to the input of the other. This results in positive and negative levels at the input of the integrator, enabling the capacitor to be charged and discharged. The Schmitt trigger receives positive and negative levels from the integrator. In this configuration, the inverting function of the integrator, the delaying effect of the capacitor, and the hysteresis of the Schmitt-trigger together ensure that the circuit oscillates. In other words, what we have on paper at this stage can be used as a signal generator.

## Sine-wave shaper

As already noted, the function generator is capable of supplying a sine-wave signal. Here, the sine-wave output is obtained from the triangular waveform. The circuit that performs this function is shown in Fig. 1c. The two anti-parallel diodes,  $D_1$  and  $D_2$ , play a crucial role. Their non-linear current-voltage characteristic causes the peak excursions of the triangular signal to be 'crushed'. The resulting waveform is a crude approximation of a sine-wave that needs to be passed

through a low-pass filter to clean up the signal.

The two diodes and  $R_{23}$  form a potential divider (p.d.). Since the lower branch of the p.d. has a non-linear behaviour (it is not a pure resistance), the ratio of the resistance in the upper branch to that in the lower branch is voltage-dependent. This is caused by the internal resistance of the two diodes, which is low at a high input voltage, and high at a low input voltage. The effect of the non-linear p.d. is that the difference between the maximum and minimum levels of the input voltage (a triangular waveform) becomes smaller. That is precisely what we are after: the peaks of the triangular wave must be 'crushed' to give the round parts of the sine-wave, and the part around the  $0\ \text{V}$  potential must be 'stretched'. The circuit in Fig. 1c achieves this goal, although its output waveform is not a perfect sine-wave.

## The complete circuit

In the circuit diagram in Fig. 2 we find the integrator,  $IC_{1a}$ , in the top left-hand corner. The Schmitt-trigger,  $IC_2$ , is seen to the right of the integrator. The circuit around  $IC_3$  provides the Schmitt-trigger,  $IC_2$ , with an accurate symmetrical supply voltage.  $IC_{1d}$  is a standard amplifier set up to function as a buffer.

The power supply of the function generator is symmetrical with output voltages of  $+15\ \text{V}$  and  $-15\ \text{V}$  with respect to ground. The previously mentioned low-pass filter is formed by the circuit based on opamp  $IC_{1b}$ . Referring back to the basic circuit diagram of the integrator, Fig. 1a, the series combination of a resistor and a capacitor makes the response dependent on the frequency of the input signal. In essence, this creates a filter function. If we want to use the capacitor to enable the circuit to 'remember' the applied voltage, its function is that of an integrator. Conversely, if we want the capacitor to introduce more attenuation for high frequencies than for low frequencies, its use in combination with a resistor creates a low-pass filter. Hence, the circuit in Fig. 1a functions as an integrator as well as a low-pass filter.

For the moment, we will consider the circuit in Fig. 1a as a low-pass filter. If a resistor were fitted in the position of the capacitor, the circuit would function as a normal, opamp-based amplifier, of which the voltage gain is not dependent on the frequency. However, because of its reactance, the capacitor makes the voltage gain of the circuit frequency-dependent. Since the reactance of a capacitor drops with frequency, the circuit functions as a low-pass filter that suppresses some of the higher harmonics of the converted triangular signal.

In the circuit diagram of the function generator, the feedback capacitor in the low-pass filter,  $IC_{1b}$ , is selected by a switch,  $S_{1a}$ . The frequency determining capacitor are  $C_5$ - $C_8$ . The integrator capacitors,  $C_1$ - $C_4$ , are also selected by a switch, in this case  $S_{1b}$ . The switches that select the components are coupled to make sure that the frequency ran-

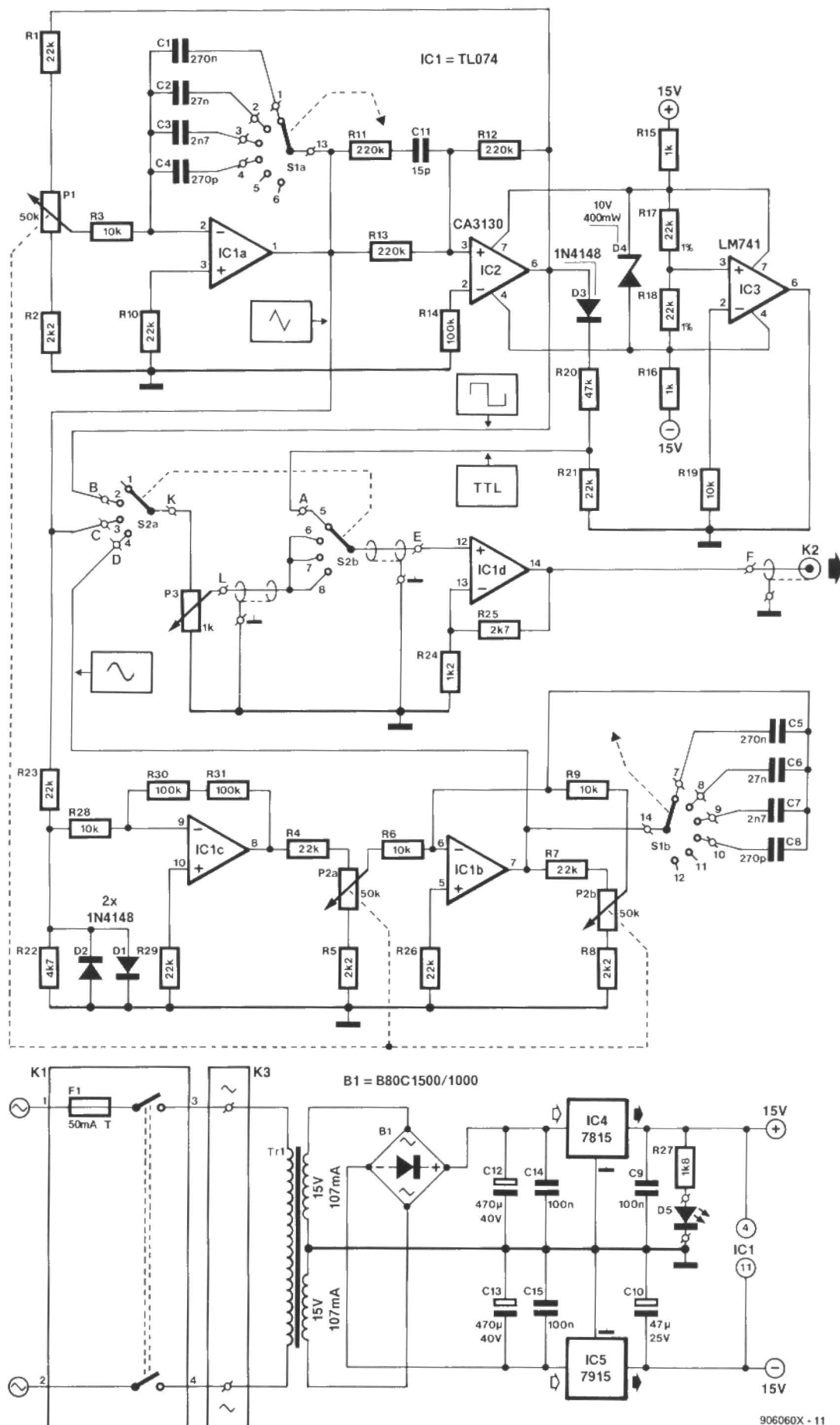
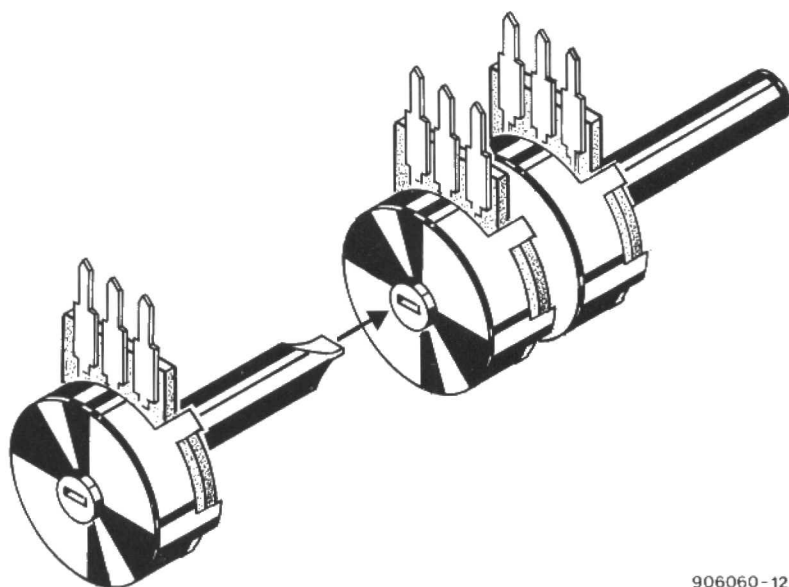


Fig. 2. Complete circuit diagram of the function generator. Note the special symmetrical power supply for integrator opamp IC2.





906060-12

Fig. 3. A little cutting and filing does the trick: how to turn a single potentiometer and a stereo potentiometer in a ganged triple type.

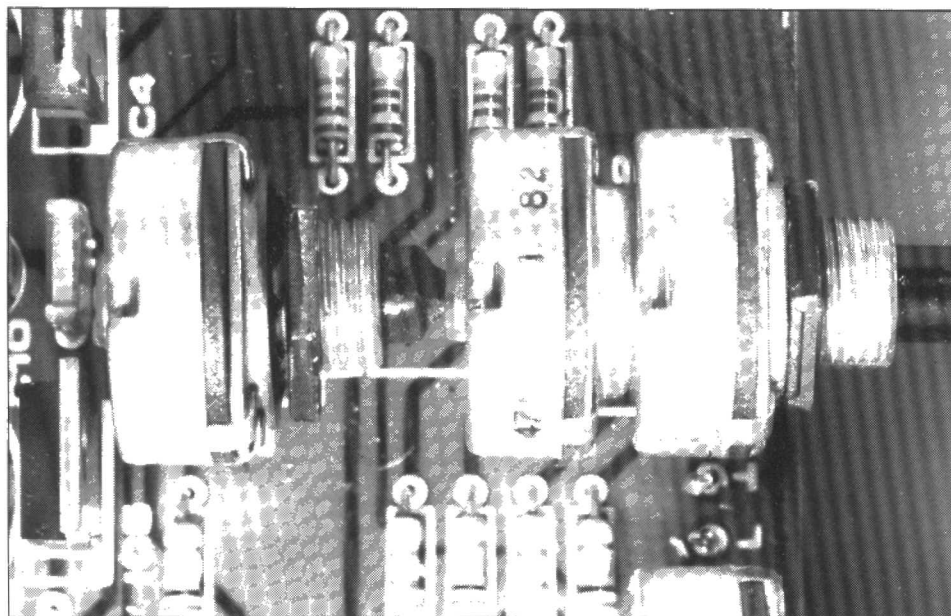


Fig. 4. Practical realization of the triple ganged potentiometer on the generator PCB.

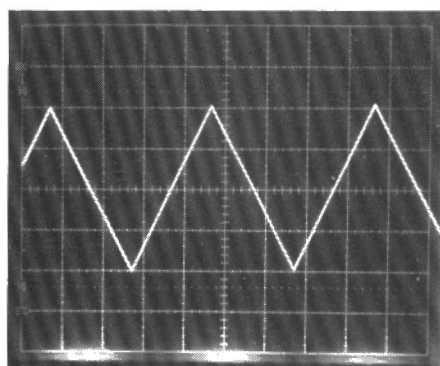
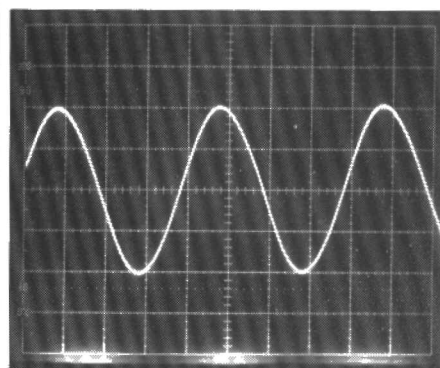
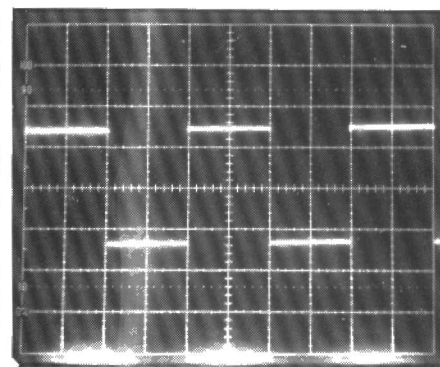
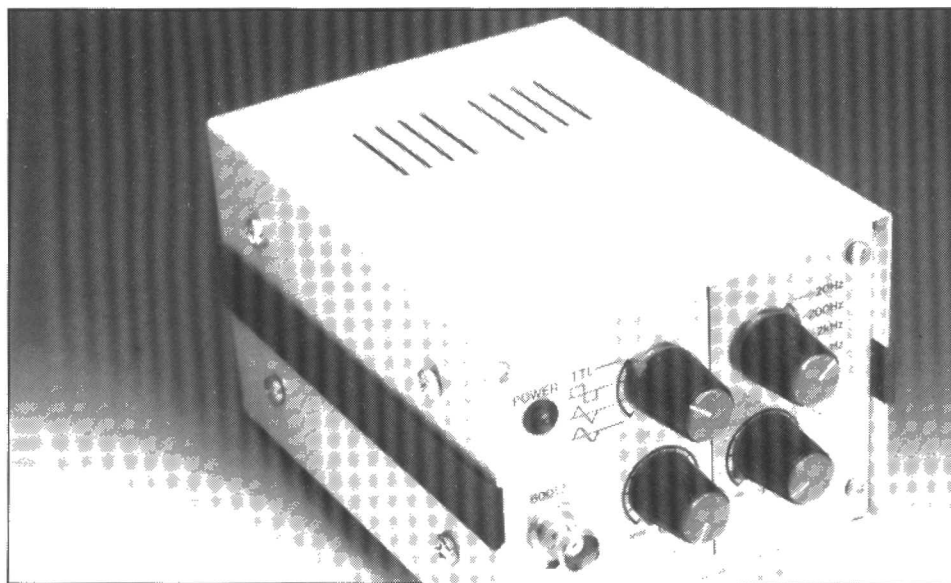


Fig. 5. Oscilloscope photographs of the waveforms produced by the function generator. Top: square wave; centre: sine wave; below: triangular wave.

ges of the low-pass filter correspond those of the square-wave/triangular-wave generator based on IC1a and IC2.

The frequency of the signal produced by the square wave/triangular wave oscillator is determined by the charge/discharge rate of the integrator capacitor, the capacitor value and the charge voltage. The coarse frequency setting is effected by selecting a capacitor with the aid of a rotary switch. A potentiometer, P1, is used for the 'fine' frequency adjustment. Two further potentiometers, P2a and P2b, are used to adjust the low-pass filter. Since the low-pass filter must track the generator frequency, P2 is coupled mechanically to P1 (see the drawing in Fig. 3 and the photograph in Fig. 4.)

The power supply of the function generator is conventional with a symmetrical 15 V output. The  $\pm 15$  V supply voltages are used for all parts of the circuit except opamp IC2, which requires a more accurate symmetrical supply voltage to ensure that its output signal is an exact square wave. Opamp IC3 forms a stabilizer for IC2. Normally, pin 3 of

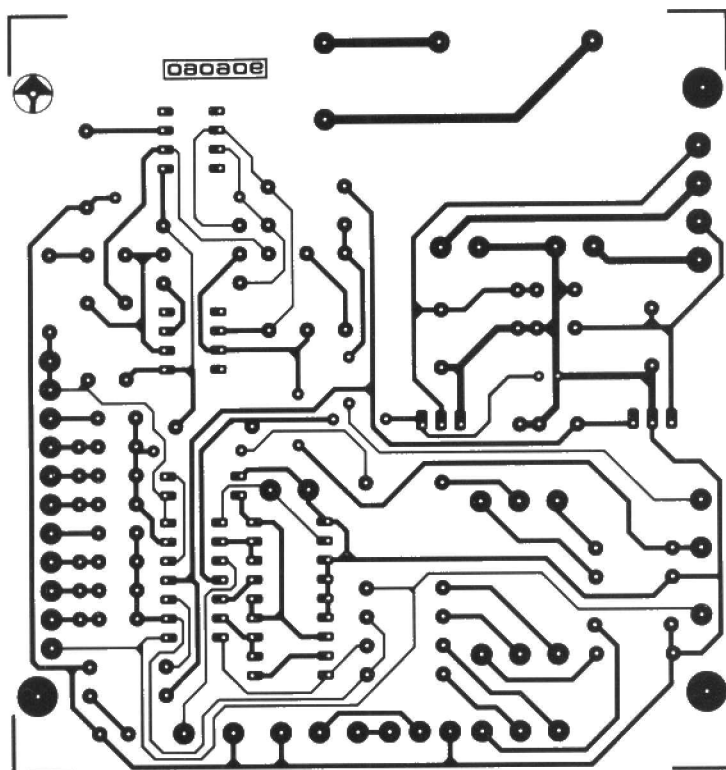
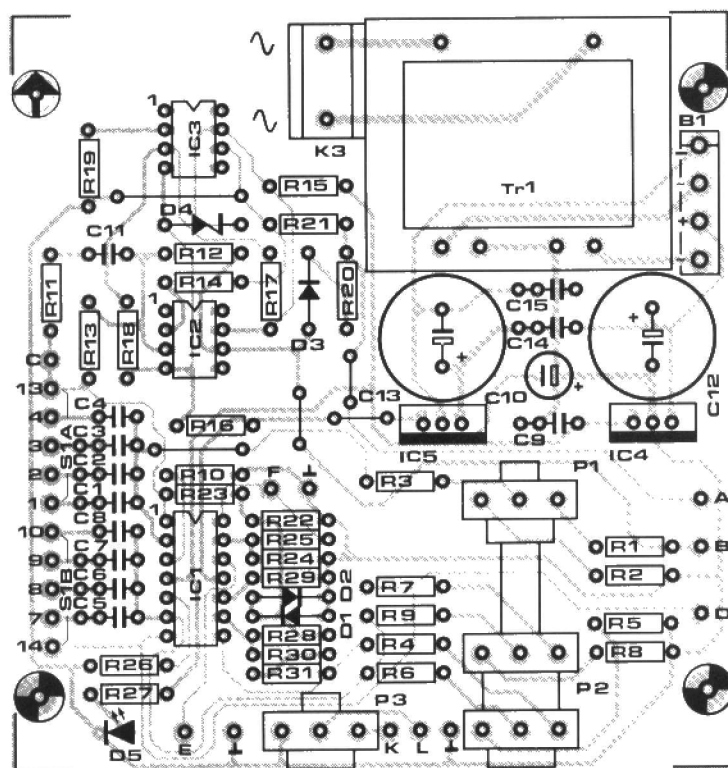


Fig. 6. Design of the single-sided printed-circuit board for the function generator. Note that the complete power supply, including the mains transformer, is accommodated on this board.

## COMPONENTS LIST

### Resistors:

8	22k $\Omega$	R1,R4,R7,R10, R21,R23,R26,R29
3	2k $\Omega$	R2,R5,R8
5	10k $\Omega$	R3,R6,R9,R19, R28
3	220k $\Omega$	R11,R12,R13
3	100k $\Omega$	R14,R30,R31
2	1k $\Omega$	R15,R16
2	22k $\Omega$ 1%	R17,R18
1	47k $\Omega$	R20
1	4k $\Omega$	R22
1	1k $\Omega$	R24
1	2k $\Omega$	R25
1	1k $\Omega$	R27
1	50k $\Omega$ linear potentiometer	P1
1	50k $\Omega$ linear stereo potentiometer	P2
1	1k $\Omega$ linear potentiometer	P3

### Capacitors:

2	270nF	C1,C5
2	27nF	C2,C6
2	2nF	C3,C7
2	270pF	C4,C8
3	100nF	C9,C14,C15
1	47 $\mu$ F 25V radial	C10
1	15pF	C11
2	470 $\mu$ F 40V radial	C12,C13

### Semiconductors:

3	1N4148	D1;D2;D3
1	10V 400mW zener diode	D4
1	LED 5mm red	D5
1	B80C1500	B1
1	TL074	IC1
1	CA3130	IC2
1	LM741	IC3
1	7815	IC4
1	7915	IC5

### Miscellaneous:

1	PCB-mount transformer 2 $\times$ 15V @ 2 $\times$ 107mA	Tr1
2	2-pole 6-way rotary switch	S1;S2
1	mains appliance socket w. built-in fuseholder and 50mA fuse	K1
1	BNC socket	
1	2-way PCB terminal block	K3
1	enclosure LC730 (manufacturer: Telet; supplier: C-I Electronics)	

IC3 is held at ground potential by a symmetrical potential divider, R15–R18. The output of IC3, pin 6, is therefore also at ground potential. However, when the  $\pm 15$  V input voltage is not exactly symmetrical (for example, when the +15 V voltage is a little higher than the –15 V voltage), the voltage at pin 3 of IC3 rises. Consequently, the output of IC3 will try to track this change by raising the output voltage. This is not possible, however, since the output is connected to ground. The result is that a positive current flows from the output of IC3 into the ground line. Since this current is supplied via R15, the voltage drop across R15 rises, so that the positive supply voltage of IC2 (pin 7) drops. In this way, the too high supply voltage is re-

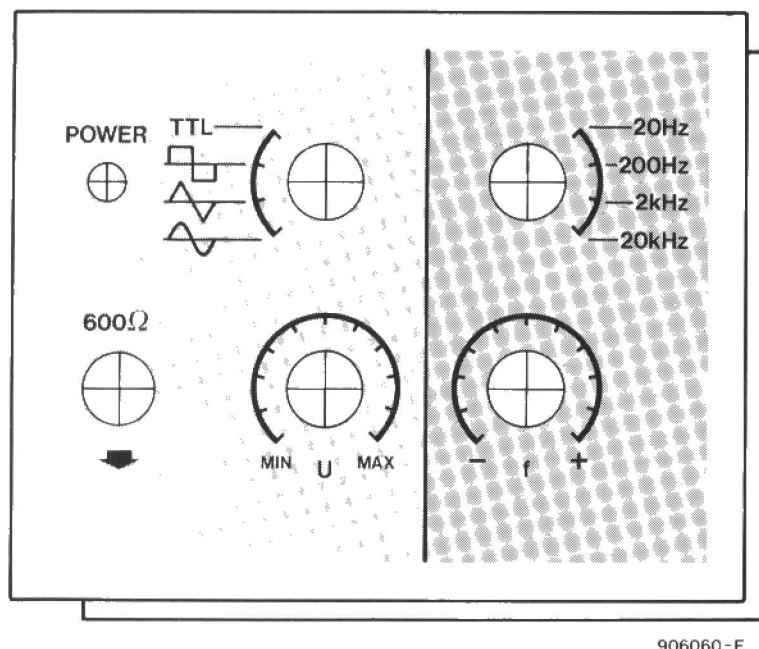


Fig. 7. Suggested design of a front panel for the function generator.

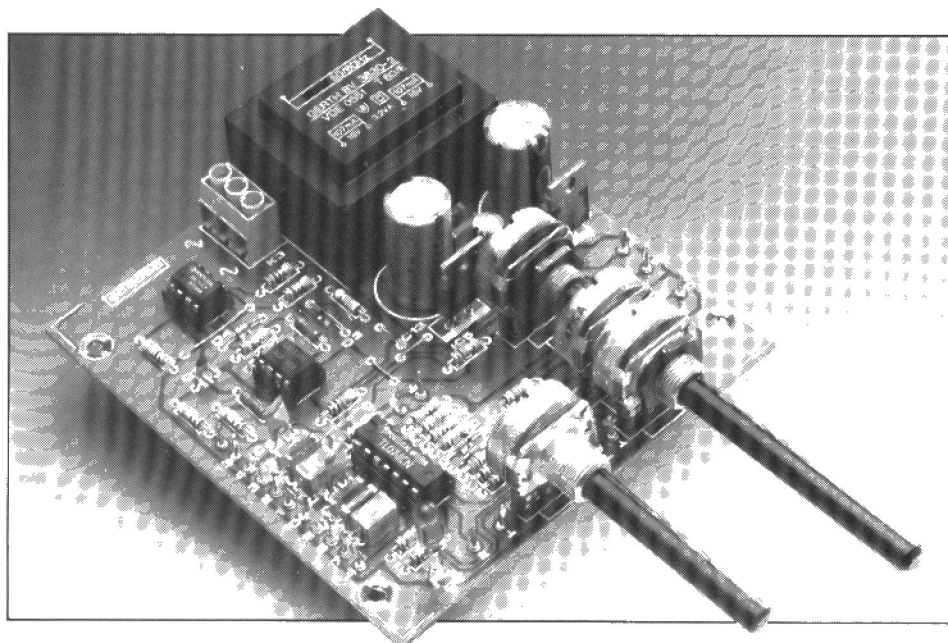


Fig. 8. Completed printed-circuit board viewed from the component side.

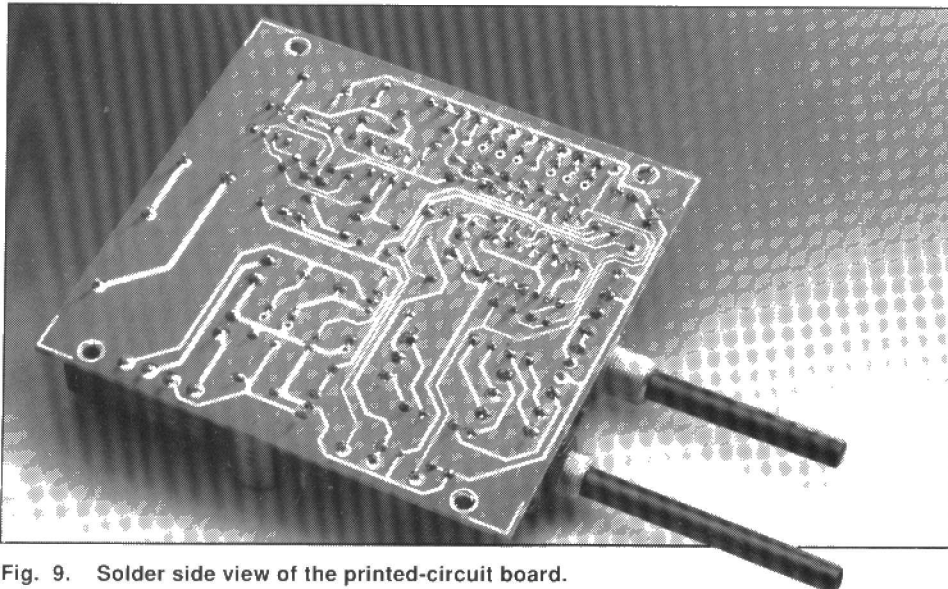


Fig. 9. Solder side view of the printed-circuit board.

duced and stabilized. The operation of the stabilizer is the same for too high levels of the negative supply voltage,  $-15\text{ V}$ . The zener diode in the stabilizer,  $D_4$ , limits the output voltage of IC2 to  $10\text{ V}_{pp}$ .

The circuit based on IC1d is a buffer with a short-circuit resistant output (connector K2). The potentiometer at the input of the buffer, P3, forms the output level control of the function generator. The output voltage available at K2 can be set between  $0\text{ V}$  and  $12\text{ V}$ .

The waveform selection is accomplished with a four-way, 2-pole switch,  $S_{2a/2b}$ , connected ahead of the buffer. The square-wave setting has two options: a fixed output voltage of  $5\text{ V}$  for TTL circuits, or  $0\text{ V}$  to  $12\text{ V}$  (variable) for all other applications. The positive half-cycles of the  $5\text{-V}$  square wave are obtained from the output voltage of IC2. A diode,  $D_3$ , passes only the positive half-cycles to a potential divider,  $R_{20}\text{-}R_{21}$  and a buffer, IC1d. The photographs in Fig. 5 show the waveforms produced by the generator.

## Construction

The function generator is best built on the printed-circuit board shown in Fig. 6. A suggested front-panel design is shown in Fig. 7. The connection of the range select switches to the board involves quite a few wires, so make sure you understand the pinning of the rotary switches. Keep all wires as short as possible. Also note that the connections to the output buffer, IC1d, are made with three screened cables (refer back to the circuit diagram in Fig. 2). The photographs in Figs. 8 and 9 show the completed circuit board, viewed from the component side and the track side respectively. The board is fitted on four short plastic PCB spacers to avoid any risk of the mains-carrying PCB tracks touching the bottom cover of the metal enclosure.

## 23/24 cm ATV RECEIVER

Following last month's review of an 23/24-cm ATV receiver by Mike Wooding\*, the suppliers, EHC (Valves) Ltd. now inform us that that the product has been substantially enhanced. Further details are available from Mr. Brian Aylward, EHC (Valves) Ltd., 7 Pavement Square, Lower Addiscombe Road, CRYDON CR0 6RD. Telephone: (081 654) 7172.

\* *Elektor Electronics* January 1991, pages 42 and 43.



# SERIAL VIDEO CARD

This design, based on a 6847 video display generator and the 8031 single-chip microcontroller, provides a simple solution to the problem of interfacing serial ASCII data for display on a monitor.

R. Grodzik

THE unit proposed here is basically a simple terminal for use with small computer systems that do not have their own display interface, but are capable of supplying serial RS-232 or inverted TTL ASCII data. The serial video card is capable of working at a selectable bit rate, and has a RAM (random-access memory) with storage capacity for up to 16 pages (or screens) of information.

As shown in the block diagram, Fig. 1, the system has two push-buttons; one is used to leaf forward through the pages of text, while the other, the reset key, is used to initialize the system, to home to the first text page, and to configure the bit rate on the serial input channel.

The unit has been designed as a minimum text display device with a reduced character set displaying upper-case characters only. Lower-case characters sent by the computer are displayed as upper case. The available character set is listed in Table 1, along with the line and page control codes.

The RAM in the system allows 16 screens of alpha-numeric data to be stored and displayed one at a time, providing a total capacity of 8,000 characters. The screen mode is

organized as 16 lines with 32 characters per line, giving 512 characters per screen. If the amount of data received at the serial input exceeds the screen capacity, the next page is automatically selected, until all 16 pages have been filled. Furthermore, there is an

automatic wrap-around facility when the earlier data in the first page is overwritten.

## Applications

I am often asked "What is it for?" or "What does it do?", when completing a design. Well, the answer is: it depends on you. Here are a few examples of what my colleagues have come up with:

- A serial keyboard which provides an ASCII encoded output (note that IBM PC keyboards are not suitable as they produce their own unique codes). The serial keyboard is connected to the input of the video card to give a basic text display terminal.
- Connected between a modem and a television receiver, incoming computer data can be displayed on your TV set. This application may be of interest to the deaf and hard of hearing.
- A video answering machine?
- A teaching aid.
- With additional battery back-up for the video RAM, text can be downloaded from a computer station for subsequent

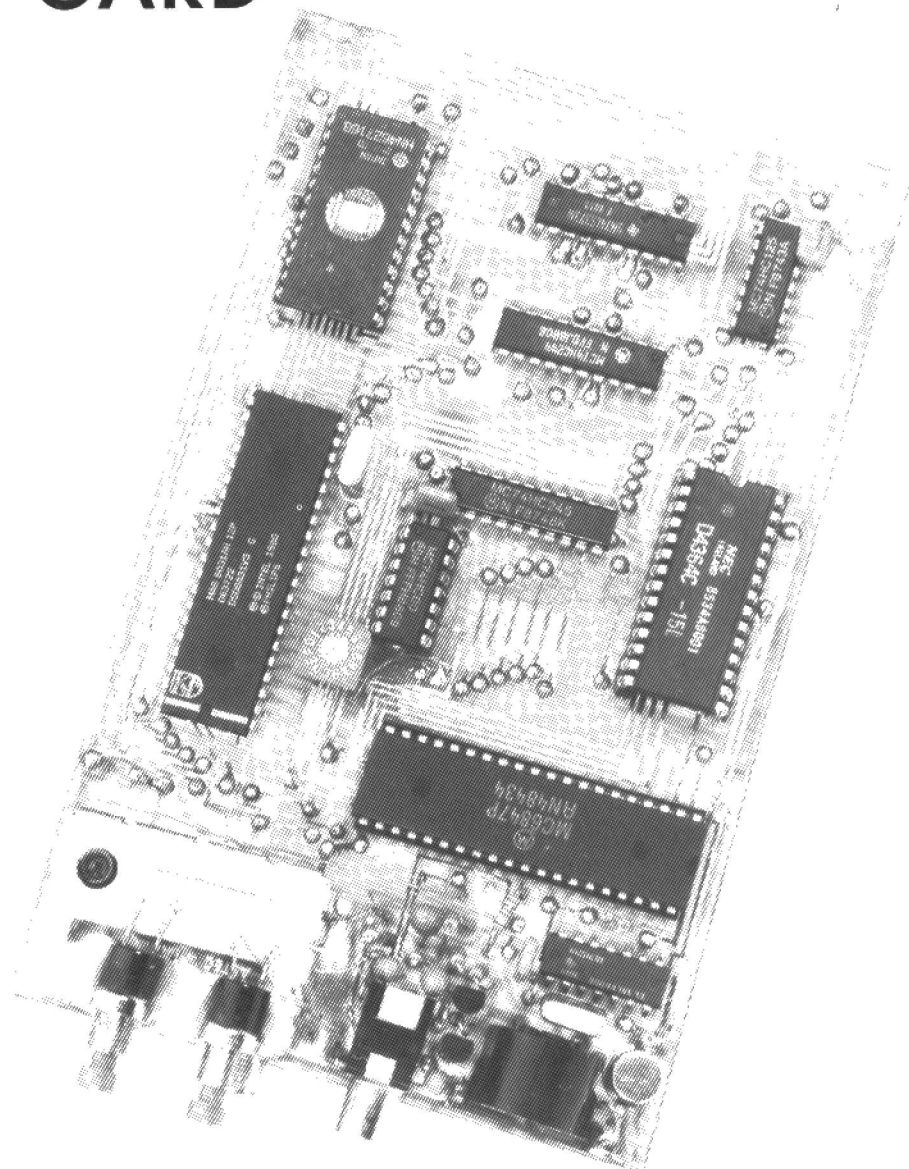


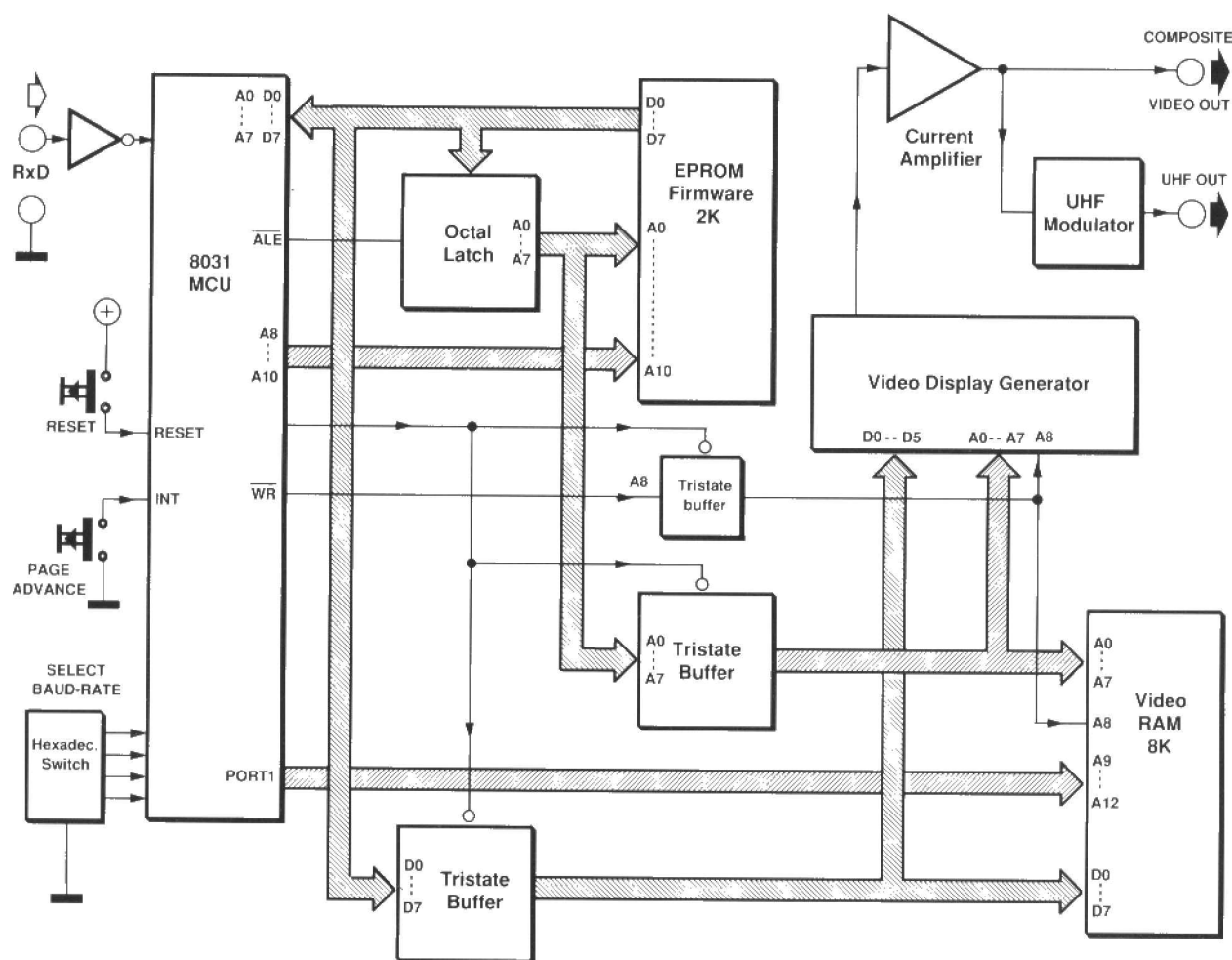
Table 1. The character set

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z						
0	1	2	3	4	5	6	7	8	9	!	"	\$	%	&	'	(	)	=	_	-	.	:	;	/	?	+	[	/	]		
→ ↑ ← (space)																															

### Control codes:

0DH	carriage return
08H	backspace
09H	horizontal tab
0AH	linefeed
0CH	next page (form feed)
0FH	clear screen

all other codes are ignored



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Fig. 1. Block diagram of the serial video card. At the heart of the circuit is a 80C31 single-chip microcontroller.

remote display on a TV set or a monitor.  
- A video carousel for promotional and advertising purposes.

## Circuit description

The complete circuit diagram of the serial video card is given in Fig. 2. On power-up, or pressing RESET button SW1, the hexadecimal switch SW3 is read by IC2, a single-chip computer, and the bit rate on the serial input channel is initialised. Table 2 lists the bit rates that can be selected by SW3. The word protocol follows the most commonly used format with 1 start bit, 8 data bits, 1 stop bit and no parity.

The serial data applied to the circuit is converted into parallel data by the system firmware, and subsequently sent to the video RAM, IC10. For this to be accomplished, the tri-state buffers IC4, IC5 and IC6 are enabled by address line A15 and WR lines of the 8031. At the same time, the video generator, IC9, and the data and address buses are switched to a high impedance state by IC8D, and the system EPROM, IC1, is disabled by A15. One databyte is thus transferred from the 8031 on to datalines D0-D5. Databit D6 is

lost since it not required by the character generator. Dataline D7 on IC10 provides a reverse video facility during the power-up self test, when the entire available character set is generated, a screenful of each character. This test feature is useful if an address or data line is open or shorted, since the monitor will show up either fault.

Once the video RAM has been updated, the tri-state buffers IC4, IC5 and IC6 are disabled, the IC9 buses are enabled, and address lines A0-A8 are strobed by IC9 to access the

ASCII data. Data goes into IC9 on lines DD0-DD5, and is converted into a composite serial video signal on pin 28 of IC9.

The video signal is inverted by transistor T1, and buffered by T2 to drive the 75  $\Omega$  load formed by the monitor input. Two outputs are provided: K2 supplies the 1 Vpp 75- $\Omega$  composite video to the monitor, while K1, the phono-type socket on the TV modulator, supplies a modulated RF signal at 591.5 MHz in the UHF TV band, for connection to the aerial socket of a domestic television receiver.

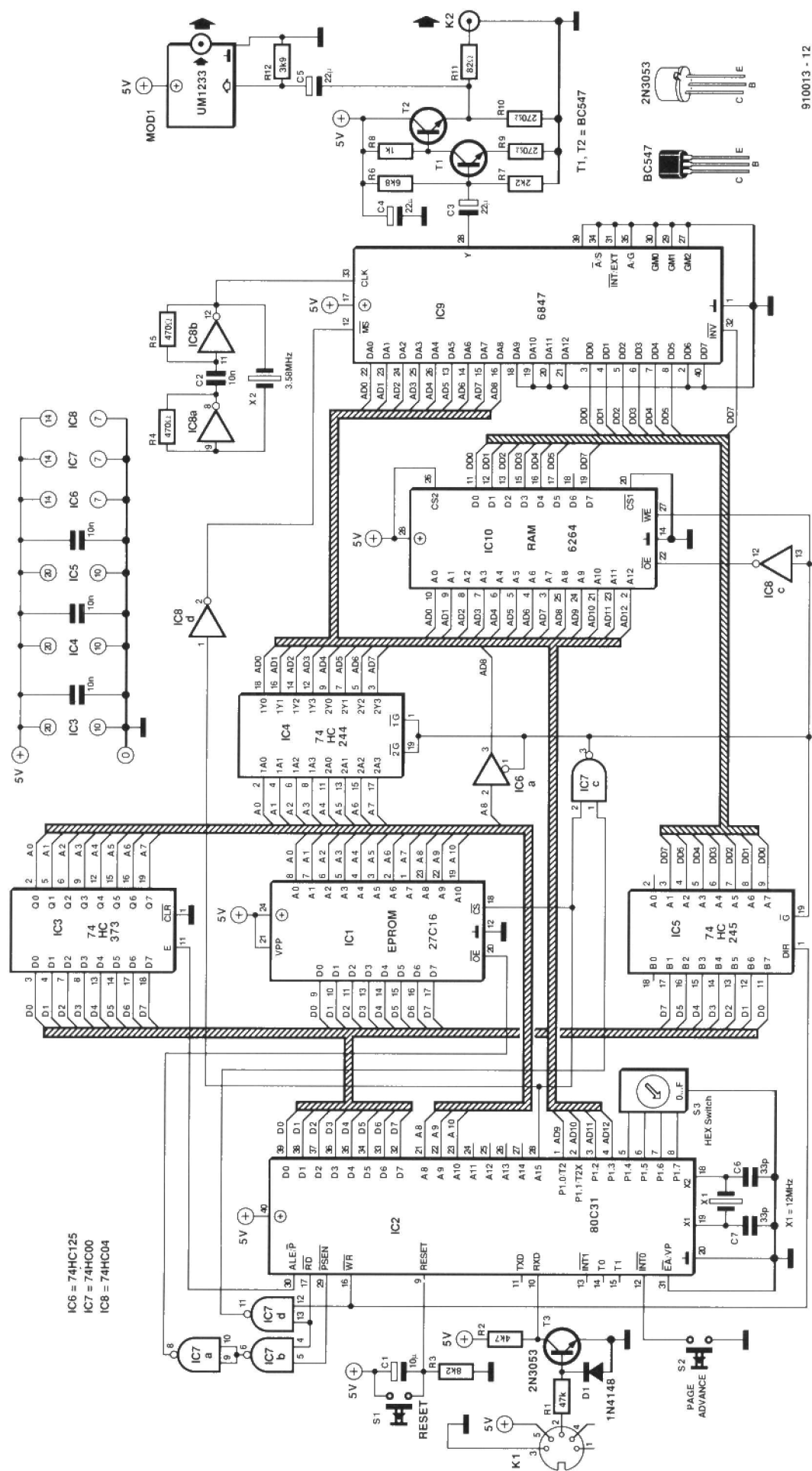
Subsequent serial asynchronous data words are fed to the video RAM. After 512 characters, port address P1.0-P1.3 on the 8031 increments, which, in turn, selects the next block of 512 locations in IC10. Address lines A9-A12 of IC10 provide 16 pages of text storage capacity.

## About the Video Generator

Each character on the screen is consists of a pattern of light and dark dots. Dot patterns for the desired characters are stored permanently in the character generator, as illustrated in Fig. 3. This simplified block

Table 2. Bit rate settings (SW3)

Position	Bit rate/Function
0	150
1	300
2	600
3	1200
4	1800
5	2400
6	power-on self test



**Fig. 2. Complete circuit diagram of the serial video card.**

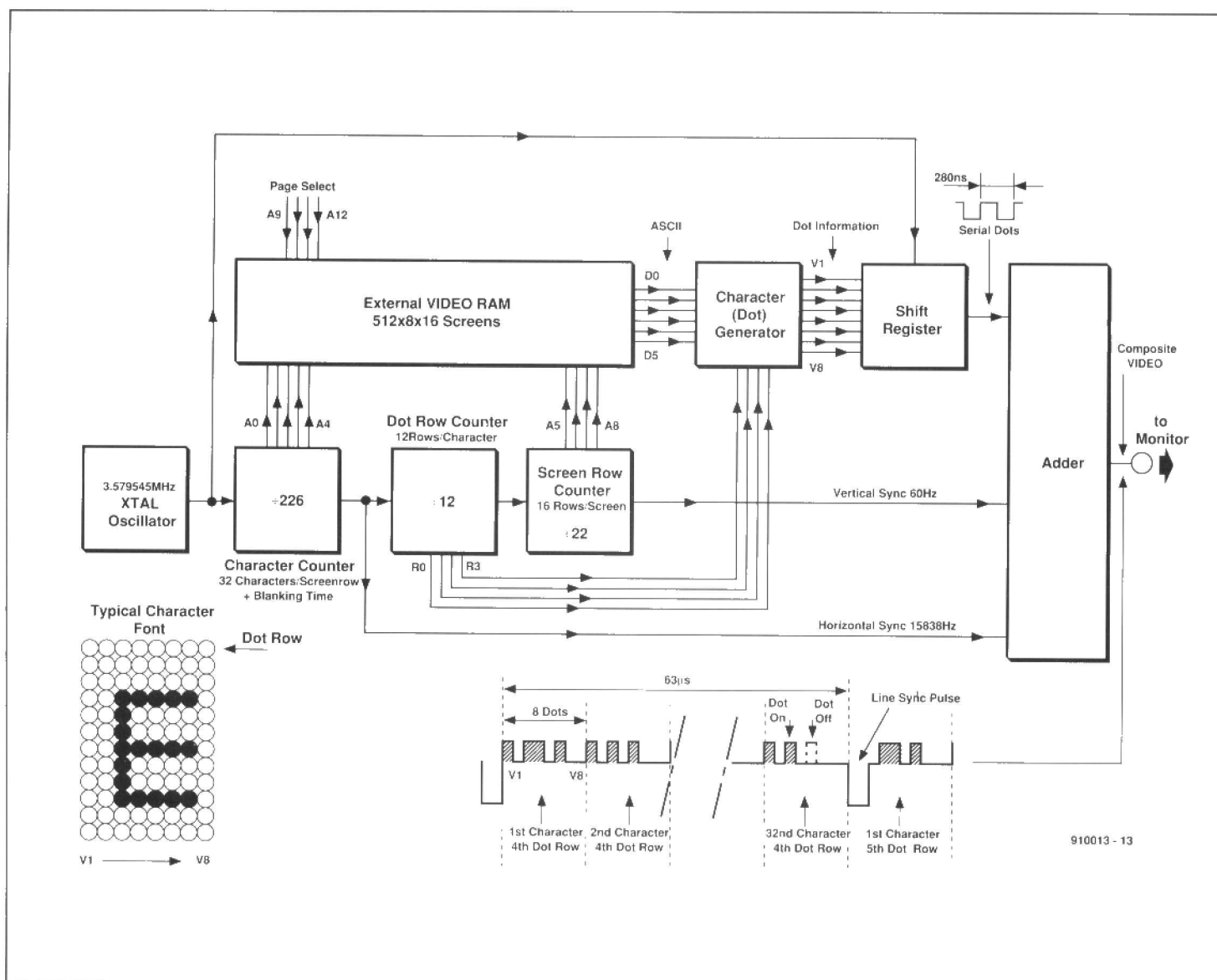


Fig. 3. Simplified block schematic of the video generator.

diagram shows how a chain of counters are cascaded to provide the timing required for the monitor circuitry.

The clock signal for the video generator is derived from an inexpensive 3.579 MHz (NTSC subcarrier) quartz crystal. The dot clock signal enables the video dots to be clocked out of the shift register. As the first ASCII character in RAM is accessed by the ÷226 counter, the character generator is addressed via data lines D0-D5. The dot information required to produce the first dot row of the character resident in the character generator is presented to the parallel-in, serial-out shift register. The dot clock is used to shift out the eight dots required to turn the CRT (cathode ray beam) beam in the monitor on or off, which produces the first line of dots for the character.

The address on lines A0-A4 increments once every eight dot clock cycles to address the next ASCII character in RAM, and the first dot row of this character is clocked out to the CRT. Address lines A0-A4 can select one of 32 characters needed for a complete line of text on the screen.

The output of the ÷226 counter produces a line sync pulse after the first dot row of all 32 characters is clocked out. The ÷12 counter

## COMPONENTS LIST

### Resistors:

1 47kΩ	R1
1 4kΩ	R2
1 8kΩ	R3
2 470Ω	R4;R5
1 6kΩ	R6
1 2kΩ	R7
1 1kΩ	R8
2 270Ω	R9;R10
1 82Ω	R11
1 3kΩ	R12

### Capacitors:

1 10μF tantalum bead	C1
1 10nF	C2
3 22μF tantalum bead	C3;C4;C5
2 33pF	C6;C7
10 100nF ceramic	IC decoupling capacitors

### Semiconductors:

1 1N4148	D1
1 2N3053	T1
2 BC547	T2;T3
1 27C16	IC1
1 80C31	IC2

1 74HC373	IC3
1 74HC244	IC4
1 74HC245	IC5
1 74HC125	IC6
1 74HC00	IC7
1 74HC04	IC8
1 6847	IC9
1 6264	IC10

### Miscellaneous:

1 12 MHz quartz crystal	X1
1 3.579 MHz quartz crystal	X2
2 push-to-make button	SW1;SW2
1 PCB-mount hex switch	SW3
1 UHF TV modulator UM1233	
1 5-way DIN socket for PCB mounting	
1 PCB-mount phono socket	
0.8 mm PCB pins	
DIL turned pin sockets	

*Note:* the pre-programmed EPROM and the PCB artwork for this project are available from R. Grodzik • 53 Chelmsford Road • BRADFORD BD3 8QN • ENGLAND. The price of the EPROM is £15.00 inclusive of P&P.



[illegible]

910013-14

Fig. 4. Hexdump of the control program that resides in the system EPROM, a 27C16.

then increments to point to the next lower row of dot patterns for the same 32 characters. As the CRT beam sweeps across the screen, the dot information of the subsequent 11 rows of each character is traced on to the screen after every line sync pulse.

When all 12 rows of all 32 characters are traced, the +22 counter increments the address on lines A5-A8, and the next screen row of 32 RAM-resident characters is addressed. The dot information for these characters is clocked out as described above. When 16 lines of characters have been dis-

played on the monitor, the final output of the  $\pm 22$  counter issues a vertical sync pulse required by the monitor circuitry to restart the raster scan, by which time all the counters have been re-initialized to zero. Thus, all 512 characters are continuously refreshed to the monitor, 60 times per second, corresponding to about three million dots per second.

External lines A9-A12 on the 8031 allow one of 16 different blocks of 512 characters to be addressed, providing a total of 16 screens of information.

In addition to the chain of counters, addi-

tional circuitry is needed to produce a blanking (beam retrace) signal for the monitor, and also to combine the vertical and horizontal sync signals with the serial dot stream. The combination of these signals is called the composite video signal.

The complex functions described in relation to the video generator circuitry are accomplished by a VLSI (very large scale integration) IC, the 6847 from Motorola. This chip thus performs the definitely non-trivial task of interfacing a microprocessor to a computer monitor or television set.

## Construction notes

The serial video card is built on a double-sided, not through-plated printed circuit board of Eurocard size (10×16 cm). The author's prototype is shown in the introductory photograph. For constructors wishing to burn their own EPROM for this project, the content of the 27C16 is given in Fig. 4.

It is recommended that all ICs be fitted in sockets, particularly IC<sub>9</sub>, which is static sensitive. The usual precautions, such as grounding the circuit board and yourself, should be taken. Be sure not to wear a nylon shirt or pullover when handling any of the ICs.

All logic ICs must be devices from one and the same family, in this case the HC series. Mixing HC series with standard 74 series ICs will produce timing errors and random display of information, since the input and output voltage thresholds are incompatible.

Ceramic decoupling capacitors should be fitted directly on the supply pins of the ICs, at the track side of the board.

Printed circuit linking pins, totalling over 150, are inserted from the component side during the initial stages of construction. The holes for these pins are drilled at a diameter of 0.8 mm. Care should be taken while soldering, since solder bridges are easily made. A watchmakers' eyepiece is useful for inspecting the board, since solder whiskers can easily evade the human eye. Once the linking pins are in place, the IC sockets are soldered in. Next, fit the discrete analogue video components. Then follows the ready-made UHF modulator, which is also static sensitive.

Finally, the power supply to the board is 5 V, at a total current consumption of about 200 mA. ■

# MIDI-TO-CV INTERFACE

Older monophonic synthesizers have the disadvantage that they cannot be controlled via a Musical Instrument Digital Interface—MIDI. Since most owners of these synthesizers, which are rightly renowned for their excellent sound, would be loath to get rid of them just yet, this article describes an interface that enables these units to be controlled via a MIDI, provided they conform to the 1 V/octave logarithmic standard.

CONNECTION to the MIDI is made via a standard MIDI IN socket that is located on the printed-circuit board of the present interface. A MIDITHRU/OUT socket enables additional MIDI compatible equipment to be controlled. The MIDI receive channel of the present interface is set via a 4-pole DIP switch.

Connection from the interface to the synthesizer is via two 6.3 mm audio connectors: one for the control voltage—CV (1 V/octave) and the other for the gate signal. Either a positive or a negative gate signal may be selected.

The interface receives MIDI note-on and note-off instructions from which it gathers the control voltage and status of the gate needed to be supplied to the synthesizer so that this produces the tones associated with the MIDI data. The MIDI code for the touch control is not involved and is of no further interest here.

In conformity with accepted standards, the interface software uses MIDI controller no. 36 as the reference tone for 0 V, that is, MIDI tone value 36, equivalent to low C on a standard 5-octave keyboard, is produced when the CV output is 0 V. The maximum tone range is 5 octaves, produced by a control voltage range of 0–5 V.

The interface is powered by an external mains-operated supply: the three required voltages are derived on the interface board.

## Circuit description

The MIDI signal is applied to serial input P3.0 (pin 10) of microcontroller IC<sub>1</sub> via the obligatory optocoupler, IC<sub>6</sub>. The program, stored in IC<sub>2</sub>, responds to note-on and note-off commands in the MIDI channel selected with switches SW<sub>1</sub>–SW<sub>4</sub>. It computes from the MIDI data the corresponding analogue voltage, later converted into digital form, and the status of the gate. The voltage is available in digital form at the 8-bit port P1, which is connected with the digital inputs of 8-bit analogue-to-digital converter IC<sub>4</sub>. The output of this converter is a voltage that is directly proportional to the digital value at port P1. The scale of the control voltage is set by opamp IC<sub>5</sub>, whose gain is varied with the aid of preset P<sub>1</sub>.

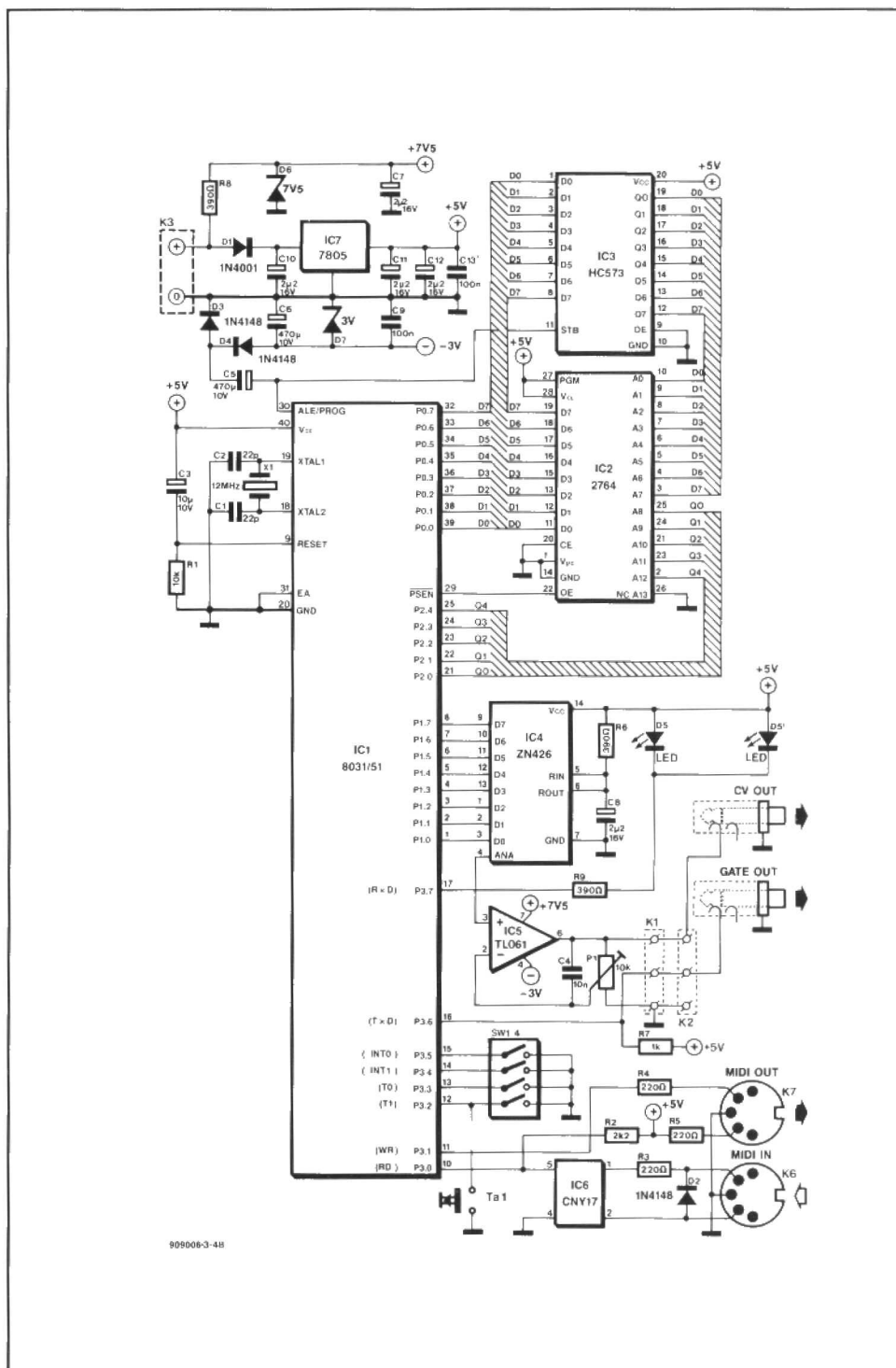


Fig. 1. Circuit diagram of the MIDI-to-CV interface.

The status of the gate is available simultaneously at port lines P3.6 and P3.7. Depending on the software, P3.6 is active high (i.e., +5 V with key depressed) or active low (i.e., 0 V with key depressed).

The heart of the interface is microcontroller IC<sub>1</sub>, which consists of an 8-bit microprocessor, 128 byte RAM, four ports of eight lines (bits) each, P0–P3, a serial interface with programmable baud rate, and two 16-bit counter/clocks. Note that the difference between a Type 8031 and a Type 8051 IC is that the former has on-board ROM. If, therefore, an 8051 is used, its internal ROM must be switched off via pin 31 (EA), since the program is stored in an external ROM. A more

detailed description of the 8031/8051 may be found in Ref. 1.

Since the 8051 has no separate terminals for address and data buses, ports P0 and P2 are used for this purpose. Port P0 serves as a multiplexed address-cum-data bus for the eight lowest bits, and P2 as that for the eight highest bits.

Circuit IC<sub>2</sub>, an eight-fold latch, assumes the eight lowest addresses from port P0 at the trailing edge of the ALE (address latch enable) signal. The eight highest addresses are provided by P2.0–P2.4. From the leading edge of the ALE signal onwards, P0 functions again as data bus.

The program is stored in IC<sub>3</sub>, an EPROM

Type 2764. Although this is available ready-programmed, it may, of course, be programmed to individual requirements.

The 8031/8051 has a complete serial interface, i.e., input and output, as required for MIDI operation. When a 12 MHz clock is used, the internal baud rate generator is adjusted via the software to operate at 31.25 kHz. The input of the interface is P3.0 (RD=read) and the output is P3.1 (WR=write).

The MIDI input circuit is based on optocoupler IC<sub>6</sub>. Input resistor R<sub>3</sub> limits the current through the photodiode, while D<sub>2</sub> protects the LED against negative input voltages. The open-collector output of the optocoupler is connected to serial input P0.3 and to

## PARTS LIST

### Resistors:

R<sub>1</sub>=10 kΩ  
R<sub>2</sub>=2k2  
R<sub>3</sub>–R<sub>5</sub>=220 Ω  
R<sub>6</sub>, R<sub>8</sub>, R<sub>9</sub>=390Ω  
R<sub>7</sub>=1 kΩ  
P<sub>1</sub>=10 kΩ, 25-turn preset

### Capacitors:

C<sub>1</sub>, C<sub>2</sub>=22 pF, ceramic  
C<sub>3</sub>=6.8–10 μF, 16 V, tantalum  
C<sub>4</sub>=10 nF, ceramic  
C<sub>5</sub>, C<sub>6</sub>=100–470 μF, 10 V, upright  
C<sub>7</sub>, C<sub>8</sub>=1.5–6.8 μF, 16 V  
C<sub>9</sub>=100 nF  
C<sub>10</sub>–C<sub>12</sub>=1.5–6.8 μF, 16 V, or  
10–100 nF, ceramic

### Semiconductors:

D<sub>1</sub>=1N4001–1N4007  
D<sub>2</sub>, D<sub>3</sub>, D<sub>4</sub>=1N4148  
D<sub>5</sub> (D<sub>5</sub>)=LED  
D<sub>6</sub>=zener, 7.5 V (ZPD 7V5)  
D<sub>7</sub>=zener, 3 V (ZPD 3V0)  
IC<sub>1</sub>=SAB8031 or SAB8051  
IC<sub>2</sub>=2764 EPROM  
IC<sub>3</sub>=74HC573, 74HCT573  
IC<sub>4</sub>=ZN426E-8  
IC<sub>5</sub>=TL061  
IC<sub>6</sub>=CNY17/II  
IC<sub>7</sub>=7805

### Miscellaneous:

X<sub>1</sub>=12 MHz crystal  
SW<sub>1</sub>–SW<sub>4</sub>=4-way DIP switch  
K<sub>1</sub>, K<sub>2</sub>=3-way pin header,  
2.54 mm grid  
K<sub>3</sub>=low-voltage socket for PCB  
K<sub>4</sub>, K<sub>5</sub>=6.3 mm (stereo) audio  
connector for PCB  
K<sub>6</sub>, K<sub>7</sub>=5-pin DIN socket for PCB  
IC socket 40-pin  
IC socket 28-pin  
IC socket 20-pin  
IC socket 14-pin  
IC socket 8-pin  
2× IC socket 8-pin  
2× insulated jumper (J<sub>1</sub> and J<sub>2</sub>)  
Heat sink for IC<sub>7</sub>  
Unregulated 9–12 V, 300 mA mains  
adaptor

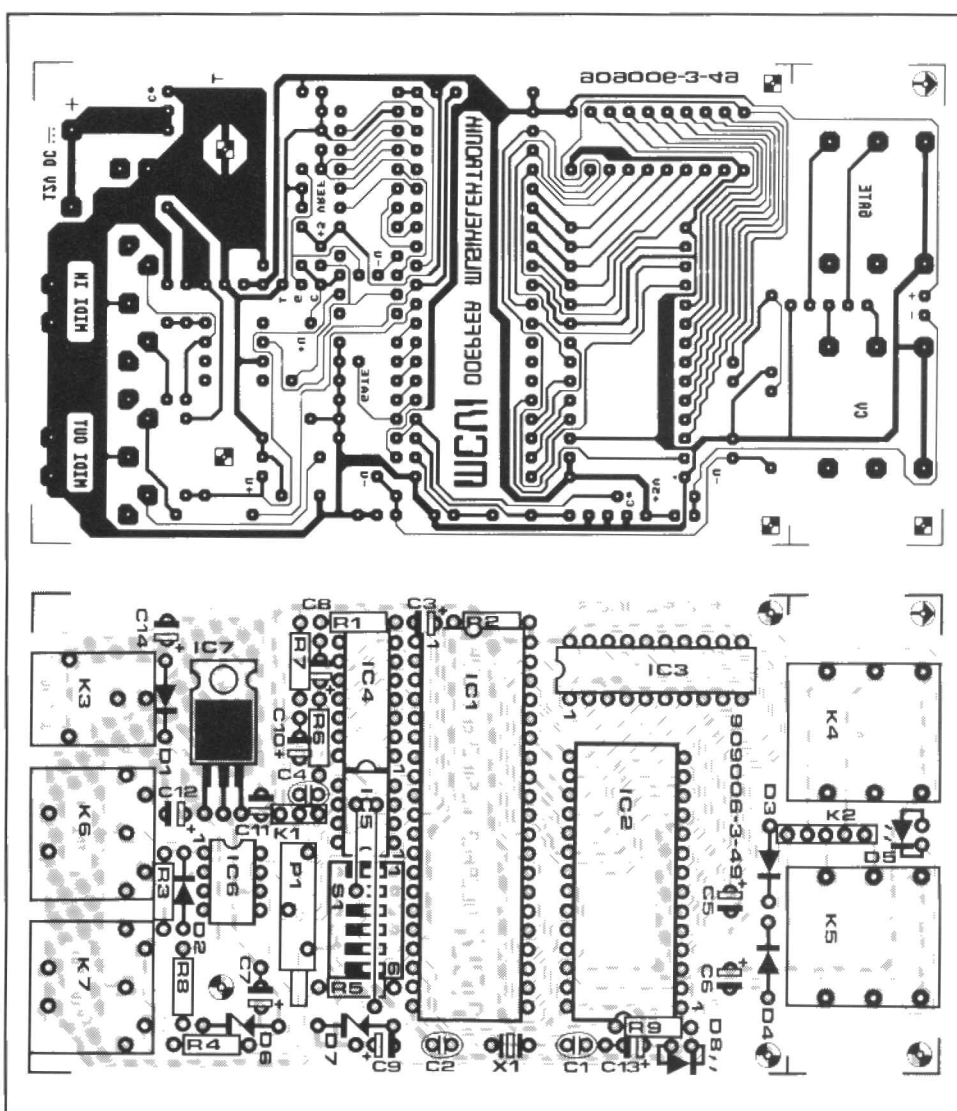
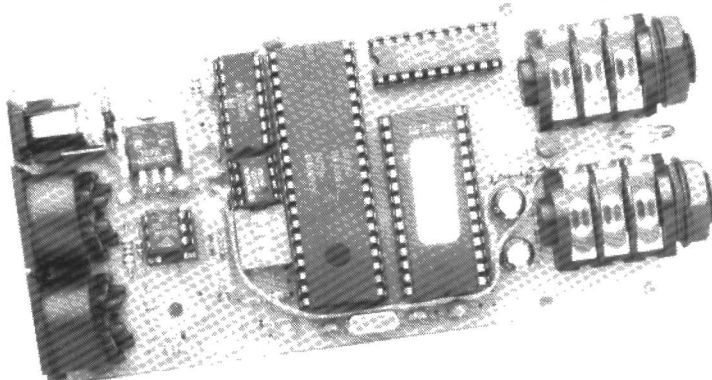


Fig. 2. Printed-circuit board for the MIDI-to-CV interface.(not available ready-made).



the +5 V supply via pull-up resistor  $R_2$ .

The MIDI OUT socket is connected via the obligatory 220- $\Omega$  resistors,  $R_4$  and  $R_5$ , to P3.1 and the +5 V line respectively.

Components  $X_1$ ,  $C_1$ , and  $C_2$  are the external elements for the internal clock oscillator of the 8031/8051; their values are as specified by the manufacturers.

Resistor  $R_1$  and capacitor  $C_3$  provide the reset signal at power-on. The EA terminal, pin 31 of IC<sub>1</sub>, is connected to earth to ensure that when an 8051 is used, its internal ROM is switched off.

Port terminals P1.0–P1.7 are connected to the digital inputs of digital-to-analogue converter—DAC—IC<sub>4</sub>. The analogue output of this device has a potential that is directly proportional to the digital value at P1.0–P1.7 and the reference voltage at the RIN input, pin 5, of IC<sub>4</sub>.

At the reference voltage output (ROUT), pin 6, of IC<sub>4</sub> a constant, temperature-stable reference voltage of 2.5 V is available. The output is connected according to manufacturers' specification to ground via  $C_8$ , to the +5 V line via  $R_6$ , and directly to RIN.

Since the analogue voltage range of IC<sub>4</sub> is only 0–2.5 V, and cannot be preset, the output voltage is applied to opamp IC<sub>5</sub>. The gain of this amplifier is preset with  $P_1$  to obtain the wanted voltage range of 0–5 V, corresponding to a tone range of five octaves. Preset  $P_1$  is a 25-turn helical type to ensure precise setting of the control voltage.

The outputs of switches SW<sub>1</sub>–SW<sub>4</sub> are monitored by ports P3.2–P3.5. Since these ports are connected internally to the +5 V line via resistors, pull-up resistors are not needed at their input terminals.

When the relevant switch is open, the associated port is high; when the switch is closed, the port is low.

The switches serve as channel selectors (MIDI channels 1–16). When the unit is switched

on, the software ascertains the position of each of the switches, which is translated into a MIDI channel number. Switch SW<sub>1</sub> has the lowest value, i.e., 1, and SW<sub>4</sub> the highest, i.e., 8. The MIDI channel numbers 1–16 result from the addition of 1 to the (converted) digital values 0–15, since the counting in MIDI technology is from 1 to 16.

Port P3.6 provides the gate signal. To ensure that its potential is high enough, the port is connected to the +5 V line via pull-up resistor  $R_7$ .

Port P3.7 provides the gate indication signal: it is connected to an LED, D<sub>5</sub>, via  $R_9$ . The other terminal of the diode is at +5 V. This way of operating the diode is advantageous, since the 8031/8051 ports can draw higher currents when they are low than when they are high. The LED lights when P3.7 is low.

The +5 V supply for the digital part of the circuit is derived from an unregulated voltage of 9–12 V, available at K<sub>3</sub>, via protection diode D<sub>1</sub> and integrated voltage regulator IC<sub>7</sub>. The interface also needs a negative and a higher positive voltage for opamp IC<sub>5</sub>. In the present circuit, these were chosen at –3 V and +7.5 V: both these voltages are stabilized by appropriate zener diodes. Note that the –3 V line can provide a current of only 0.5 mA maximum. It is therefore impossible to replace the Type TL061 by an 'equivalent' type, such as the  $\mu$ A741, TL081 or TL071, since all these draw a higher current and this would damage the –3 V part of the power supply.

## Construction

The entire interface is housed on the printed-circuit board shown in Fig. 2. Only two wire bridges are needed: 'U' and 'gate'.

If audio connectors are used for CV-OUT and Gate-OUT, two jump leads ( $J_1$  and  $J_2$ ) must be connected between K<sub>1</sub> and K<sub>2</sub>. Diode D<sub>5</sub> must be soldered between K<sub>4</sub> and K<sub>5</sub>. The terminals of this LED should be bent by 90°.

If audio connectors are not used, the CV and gate take-off, as well as the ground connection, are at K<sub>1</sub>. Diode D<sub>5</sub> must be fitted next to  $R_9$ . The relevant part of the board not used may then be cut off along the dashed line to make the board smaller and more suitable for fitting into an existing equipment.

Note that K<sub>2</sub> has two additional soldering points to enable the use of stereo connectors for both

CV and gate.

## Test

Do not yet plug in the ICs and switch on the mains. Check that the +5 V ( $\pm 5\%$ ) and +7.5 V ( $\pm 10\%$ ) supplies are present. If not, a short-circuit, a defect capacitor, or one that is connected with incorrect polarity, may be the cause.

Switch off the mains and insert all ICs into their sockets. Switch on the mains and check that the 3 V ( $\pm 20\%$ ) supply is present. Also, when the mains is switched on, D<sub>5</sub> or D<sub>5</sub>' should light briefly to indicate that the reset routine is effected. If it does not, there is a short-circuit, defect component, or the LED has been connected with incorrect polarity.

Set the DIP switch to the required MIDI channel as shown in Fig. 3 and connect a suitable MIDI sender to the MIDI-IN socket on the interface board. When the sender transmits on the selected channel, diode D<sub>5</sub> or D<sub>5</sub>' should light when an note-on instruction activates the gate signal. When the relevant key is released, and a note-off command is thus given, the LED should go out.

Next, press the reference key, which is normally C<sub>2</sub> (MIDI code 36), and check that the control voltage is 0 V. If it is not, jot down the difference. Then, press a key five octaves higher (C<sub>3</sub>) and adjust  $P_1$  until the control voltage is exactly 5.000 V (or 4.000 V if a four-octave keyboard is used) plus or minus the difference noted before.

If the circuit does not operate satisfactorily and no apparent fault can be found, check whether there is a 12 MHz signal at pins 18 and 19 of the microprocessor (showing that the internal oscillator functions) and whether at reset pin 9 the level briefly becomes +5 V and then drops back to zero when the mains is switched on. Also, check the board for short-circuits or breaks of the tracks, whether all ICs have been inserted properly into their sockets, and whether the EPROM is of the correct type.

## Switched trigger modification

Some synthesizers do not operate with a gate signal but with a switched trigger. The waveform generator in these is not started by a voltage pulse but by a switched contact. To control such synthesizers via the present interface, an additional 10 k $\Omega$  resistor and a general-purpose n-p-n transistor should be connected as shown in Fig. 4.

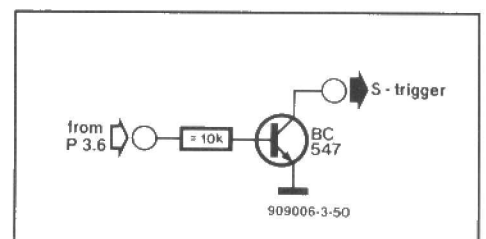


Fig. 4. Extension circuit for working with switched trigger equipment.

Reference: The 8031/8731 microcontroller  
Elektor Electronics – July 1990, p. 36.

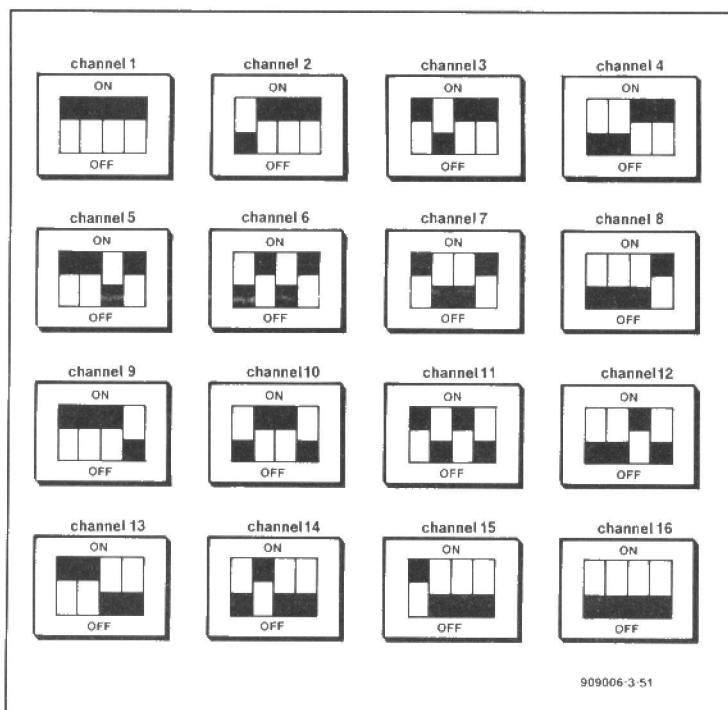


Fig. 3 Setting of MIDI channels with the DIP switches.



# RADIO DATA SYSTEM (RDS) DECODER

Since our first publication on RDS almost two years ago, the system has met with rapid acceptance by European radio broadcasters. At the time of writing this follow-up article, the experimental status of RDS on which we reported earlier is nearly ended, and there are currently car radios as well as FM tuners that can be bought with an RDS decoder as a built-in feature. For all of you who have a perfectly working FM radio without an RDS demodulator/decoder we present two add-on circuits, an RDS demodulator and an RDS decoder, that implement the main features of this new service with the aid of an LCD read-out.



Dr. Ing. M. Ohsmann

When we first published an article (Ref. 1) on the main features and the technical background of the Radio Data System (RDS), we added a circuit of an RDS demodulator to help interested readers on the way to designing a stand-alone decoder. As explained, the demodulator, based on the SAA7579T from Philips Components, is to sit between the FM tuner and a microprocessor system. Its function is to extract the RDS data from the received signal, and supply a number of digital signals for use by a decoder. The decoder was not described at the time, and various readers have made suggestions for the design of such a unit.

In this article we will recapitulate some of

the basic information on RDS contained in Ref. 1, repeat the circuit of the SAA7579T-based RDS demodulator, and propose a microprocessor-controlled decoder that supports the main functions of the RDS system.

## RDS features supported

If you are interested in a full technical background to RDS, and a complete description of all the features offered by this system, there is only one thing to do: order a copy of the relevant EBU specification, Technical Document 3244-E (Ref. 2). You will find this document invaluable while experimenting with RDS reception and decoding, since it

contains a full explanation of the modulation, signal encoding, and all code structures used.

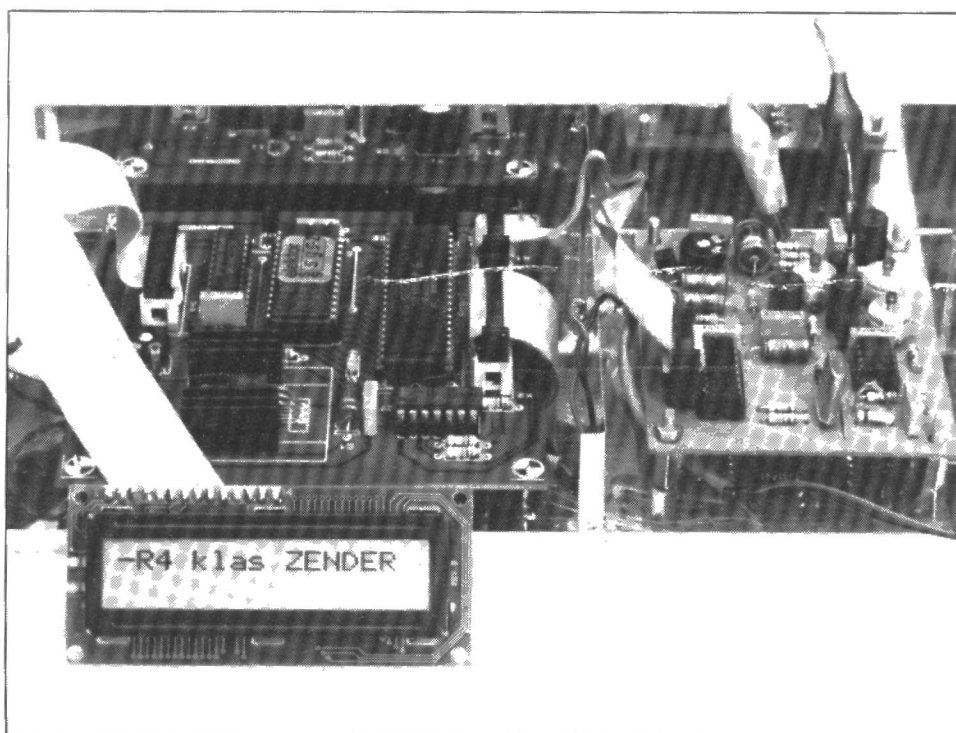
The structure of the RDS system allows so-called features to be added or omitted depending on the RDS Group Type defined by the EBU (see Table 2 in Ref. 1). Since the experimental status of the system has been abandoned in many European countries, the list of features has grown to quite a length. However, radio station operators are, in principle, free to make a selection of the features they wish to implement. Hence, whether or not a certain RDS feature is implemented or not depends on the country, the region, and even the radio station you are tuned to. Fortunately, there seems to be a consensus as far as a set of basic features is concerned. In fact, the EBU makes a distinction between three classes of RDS features: primary, secondary and additional. The present decoder supports three of the four primary features (PF), and two secondary features (SF). The function of each of these features is discussed below.

### PI: Programme Identification (PF)

This code allows the receiver to distinguish between countries or areas in which the same programme is transmitted, and the identification of the programme itself. The PI code is not normally displayed, and functions in conjunction with an Alternative Frequency (AF; also a primary feature) list, stored in the RDS decoder. The AF list enables the receiver to be retuned automatically for best reception of a particular programme.

### PS: Programme Service name (PF)

The PS code contains a text consisting of a maximum of ten alphanumeric characters that form the station name or a meaningful



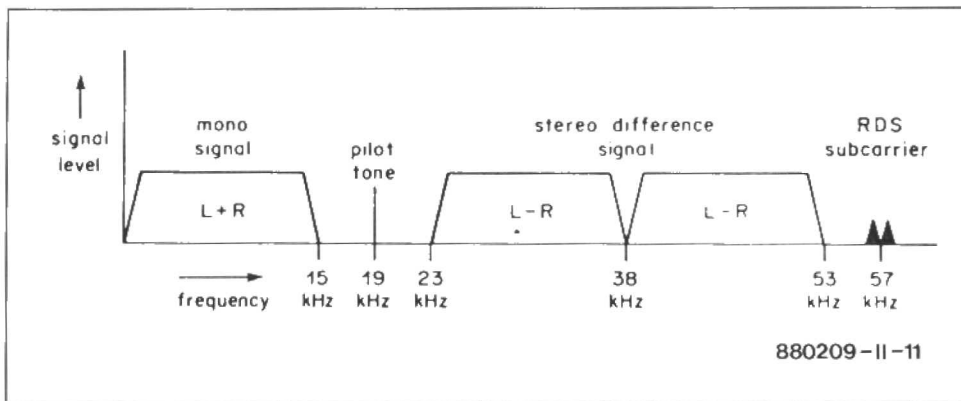


Fig. 1. Spectrum of the baseband transmitted by a VHF FM broadcast transmitter modulated with a stereo multiplex signal plus associated pilot tone, and the RDS datastream.

abbreviation of it. The characters are defined by the ISO-646 standard, and correspond to ASCII codes as far as letters and numbers are concerned. The PS indication is particularly useful for domestic receivers, since the VHF FM band in many areas is so crowded these days that it is almost impossible to find a particular station quickly just by listening.

#### TP/TA: Traffic Programme / Traffic Announcement (PF)

These are essentially on/off codes that indicate whether a particular transmitter carries traffic information or not. The signal may be used for turning a cassette or compact disc player in the car, or a signalling device, on and off. Alternatively, TP/TA information may be used in conjunction with an automatic station search function in a radio.

#### PTY: Programme Type (SF)

A total of 31 codes is available to indicate the programme type. Examples are 00001 for News, 00100 for Sports, and 01110 for Folk Music.

#### RT: Radiotext (SF)

This code accommodates a 64-character text string which may be programmed freely by broadcasters. It often contains supplemental

data on the current programme, music titles, announcements, and the like. In some cases, RT is also used for traffic announcements.

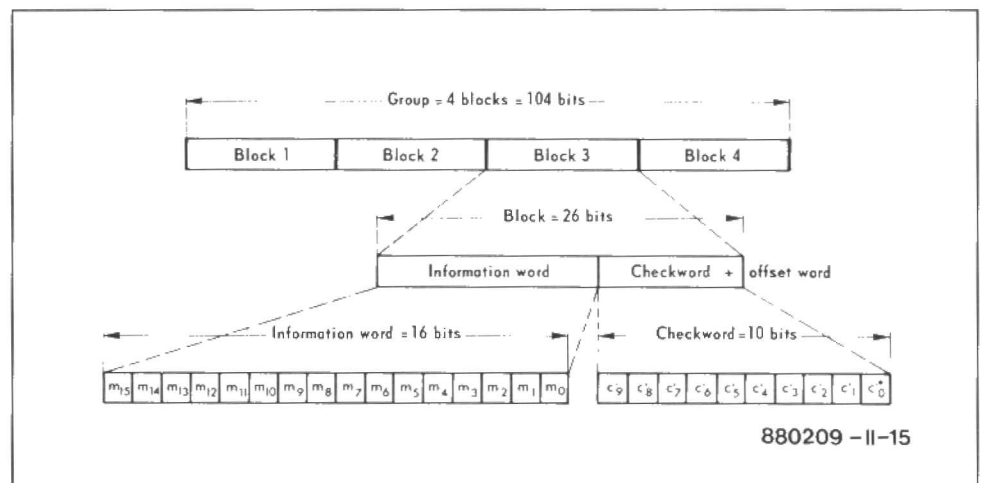


Fig. 2. Structural analysis of the RDS data format (illustration reproduced by courtesy of the European Broadcasting Union).

### RDS on the air

The RDS datastream generated by the broadcaster is modulated on to a subcarrier added

to the baseband transmitted by the VHF FM station. In most cases, the baseband will already contain the stereo difference signals L-R and L+R, plus the associated pilot tone at 19 kHz.

The RDS system uses a subcarrier frequency at 57 kHz, which is locked either in phase or in quadrature phase to the third harmonic of the 19 kHz pilot tone. The resulting baseband spectrum is shown in Fig. 1. Interestingly, in Germany, the 57-kHz subcarrier is not completely suppressed since it is also used for the ARI (Autofahrer Rundfunk Informationen, or motorists' broadcast information).

The RDS subcarrier is suppressed and amplitude-modulated by the bi-phase coded RDS datastream. The formal classification of this modulation system is 'double-sideband with suppressed carrier', or DSSC. However,

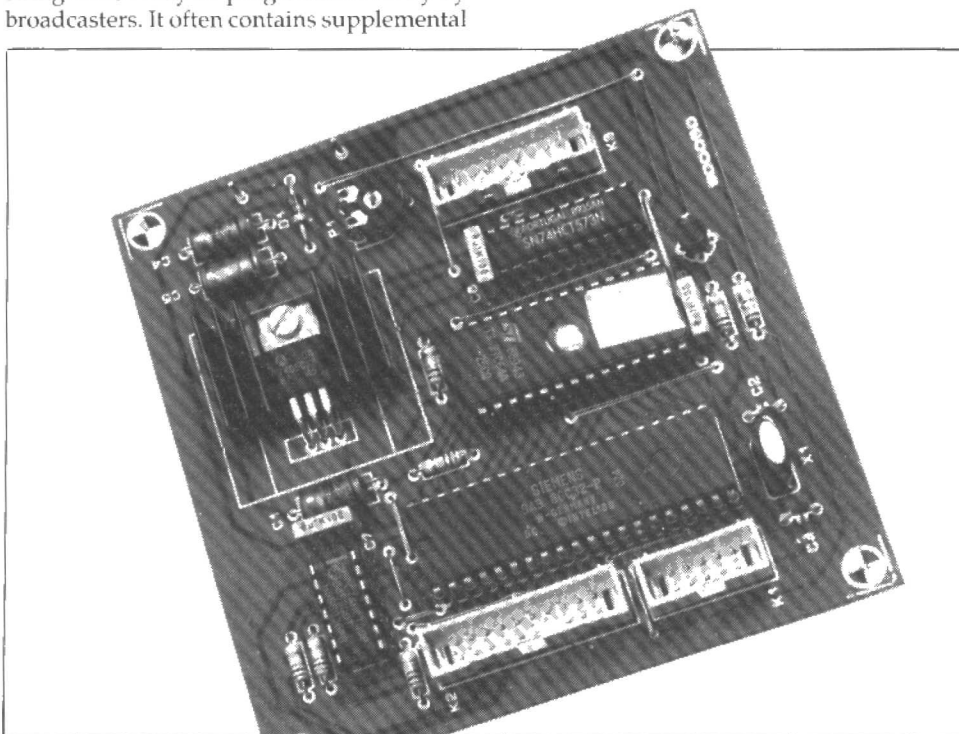
since a bi-phase coded modulation signal is used, the qualification 'two-phase phase-shift keying' (PSK) may also be applied, bearing in mind that the phase deviation is 90°. The bandwidth of the RDS sidebands in the baseband spectrum is roughly equal to the databit rate of 1187.5 per second.

### RDS: basic structure

RDS data consists of 16-bit words, accompanied by a 10-bit checksum for synchronization purposes. The two are referred to as an RDS block. As shown in Fig. 2, the MSB (most significant bit) of the dataword is always transmitted first. Four RDS blocks together form an RDS group. Since all data is transmitted continuously without gaps between blocks or groups, the group transmission time is 87.5 ms.

The 10-bit checksum with every dataword is a so-called CRC (cyclic redundancy check) that ensures high reliability of the RDS even under adverse reception conditions. Like the dataword, the CRC is transmitted MSB-first.

The status of each RDS group is marked by the first five bits (MSBs 15 through 11) in block 2. The first four bits, 15 through 12, indicate the group number, the fifth bit the



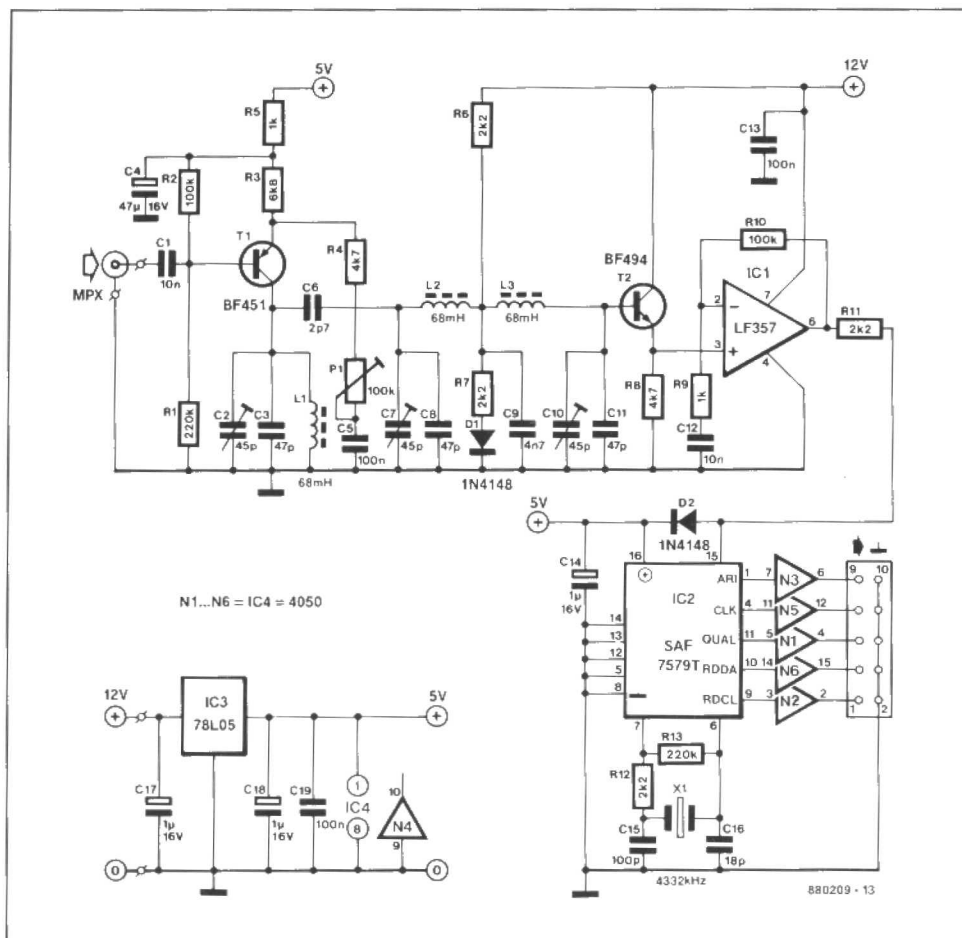


Fig. 3. Circuit diagram of the SAF7595T-based Radio Data System decoder.

group type, A or B. All group types contain two of the previously mentioned primary RDS features, PI and TP, and one secondary feature, PTY. This means that these RDS codes have the highest repeat rate. The other codes used by the present decoder are contained in the fourth block. The third block contains either the PI data (group type B), or the alternative frequency (AF) list (which is not used by the control program of the decoder described here).

## An RDS demodulator

The circuit diagram of the SAF7579T-based RDS demodulator is shown in Fig. 3. The baseband signal supplied by the FM tuner is amplified by transistor T1 and subsequently filtered in a three-section 57-kHz band-pass filter. The filter consists of fixed inductors L1, L2 and L3, and trimmer capacitors C2, C7 and C10, each with a parallel capacitor to ensure the correct tuning range. The gain of the transistor amplifier can be set with the aid of preset P1, as required for the output level of your FM tuner. The filtered 57-kHz signal is buffered by emitter follower T2, whose d.c. operating point is defined by voltage divider R6-R7. Next, opamp IC1 amplifies and digitizes the 57-kHz signals.

The actual demodulation of the two 57-kHz sidebands takes place in IC1, a SAA7579T or SAF7579 from Philips Components. Since the operation of this IC has been covered extensively in Ref. 1, a summary is appropriate here. It should be noted that the SAA7579T is now obsolescent, and will be

superseded by the SAF7579T, which has basically the same characteristics. Both ICs work all right in the demodulator.

The internal diagram of the SAF7579T is given in Fig. 4. The digitized 57-kHz signal supplied by the previously discussed amplifier/filter circuit is applied to a Costas-loop which includes a 4.332 MHz oscillator. The loop circuit recovers the modulation signal from the sidebands, and regenerates the 57-kHz carrier, which is divided internally to obtain the 1187.5-Hz clock signal, RDCL (output pin 9). The actual demodulation of

the RDS signals is based on a bi-phase symbol decoder and a phase difference decoder. Chip output pin 10 supplies the RDDA (RDS data) signal, which is synchronous with RDCL. Relative to the clock, data are valid for 417  $\mu$ s after a clock transition, irrespective of whether referenced against the positive or the negative pulse transition. This forces data changes, i.e., the toggling of RDDA, to take place 4  $\mu$ s before a clock transition.

A third signal, QUAL, is used to indicate that the received signal contains valid RDS data, i.e., its reception quality is good enough for the decoder to recognize data and sync.

The last point to note here is the frequency of the quartz crystal. Unfortunately, this frequency has caused confusion with some constructors of the demodulator because it looks very much like the familiar PAL colour frequency, 4.433 MHz. The required quartz crystal frequency is, however, 4.332 MHz; the demodulator does not work properly with a PAL colour crystal.

## The decoder: a 80C32 single-board computer

The RDS decoder proposed here is a basically a single-board computer (SBC) based on the 80C32 microcontroller. The function of the decoder is to translate the information received from the RDS demodulator into characters on a liquid-crystal display (LCD). The SBC used here is not purposely designed to function as an RDS decoder; it is the EPROM-based control software only that implements this particular application. The hardware of the SBC is a fairly 'open' design, and may be used for other applications that require some form of intelligence in the form of a microcontroller running an application program from EPROM.

The heart of the SBC is formed by the 80C32 single-chip microcontroller in a conventional application circuit. The lower address byte is decoded with the aid of a latch,

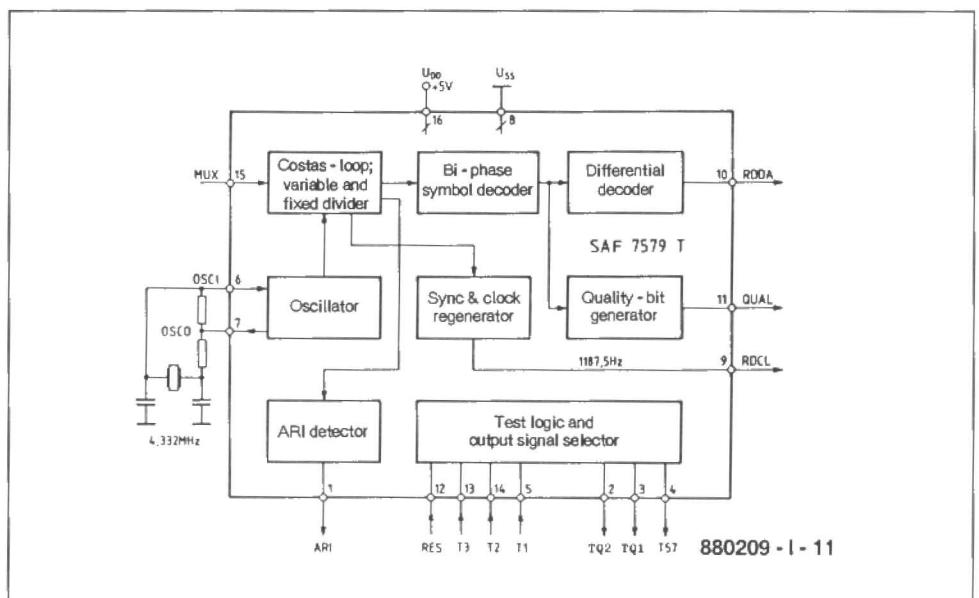
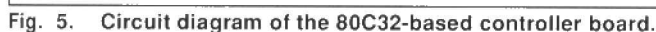


Fig. 4. Block diagram of the SAF7595T (courtesy Philips Components).



The LCD is connected to the databus via a box header, K3. Data for the display is copied from the databus with the aid of a latch signal supplied by NAND gate IC1D, which

The TTL-level RDCL, RDDA and QUAL signals from the demodulator are applied to the 80C32 via connector K1. The clock signal,

The 'minimum' user interface of the decoder is shown in Fig. 6. All the controls are connected to the CPU via K2 and port P1. Although port lines P1.0, P1.1 and P1.2 are buffered, they are not used by the RDS decoder software. They are, however, at the programmer's disposal when the SBC is used for another application.

Finally, the SBC has its own, on-board, 5-V power supply that allows the circuit to be powered from the car battery.

When the decoder is switched on, or after a reset, the LCD briefly shows an 'OK' message. Next, the control program will attempt to decode the signal supplied by the RDS demodulator. If the RDS signal is present and good enough, the programme identification, PI, is displayed in hexadecimal notation in the left-hand four character positions of the LCD text line (see Fig. 7). Then follow a colon (:) and the 2-character PTY (programme type) code, also in hexadecimal. The next character is either a + or a - (TP code), depending on whether the received station carries traffic information or not. When an traffic announcement is broadcast (TA=1), the colon changes into a solid rectangle. The



Fig. 6. Connection of the controls to header K2 on the processor board.



last eight character positions on the LCD are reserved for the PS (programme service) indication.

In addition to the above 16 characters, the display stores another 64. These positions are reserved for the RT (radiotext) function. Switch S1 allows you to shift the 16-character wide window, so that the radiotext (if transmitted) appears on the LCD. The other two switches, S2 and S3, serve to clear the display and to reset the decoder respectively.

A special test mode may be entered by keeping S2 pressed during a reset. The control program then measures and displays the number of errors that occur in the demodulated RDS datastream during an interval covering 1,000 pulse transitions. The test mode is particularly useful for the alignment of the demodulator.

## Construction

The construction of the demodulator board (Fig. 8) and the decoder board (Fig. 9) is straightforward, and merits almost no detailing, with the possible exception of the mounting of the SAA7579T (or SAF7579), which is a surface-mount (SMA) chip. Not to worry, though: if you use a low-power

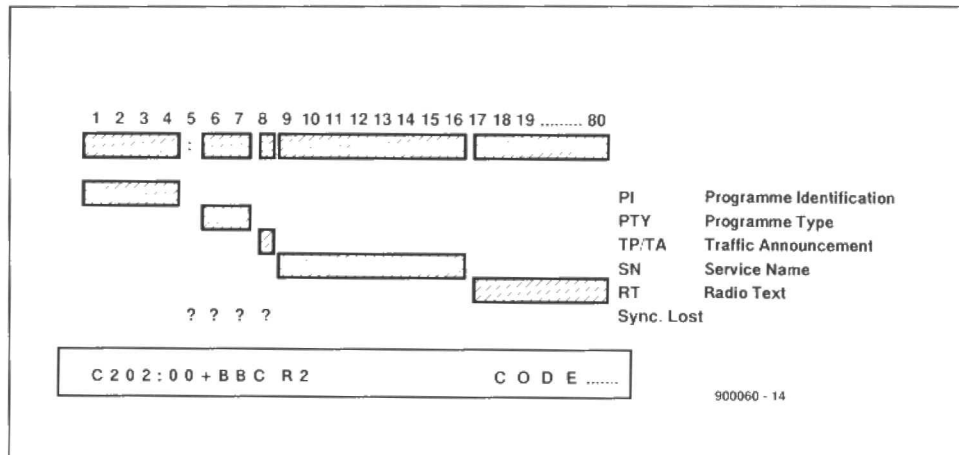


Fig. 7. Positions reserved for the RDS data that appears on the LC display.

solder bit with a fine tip, and solder quickly and carefully, you will have no trouble whatsoever dealing with this tiny, yet essential, component. Inductors L1, L2 and L3 are radial types from the 181LY series from the Japanese manufacturer Toko Inc.

The completed boards must be screened since they radiate pulses that could cause interference in the FM tuner. The prototypes were mounted in RF-tight enclosures cut and bent to size from tin plate. The demodu-

lator input of the decoder, the connection for the controls (K2) and that for the display (K3) are preferably made with sub-D sockets and plugs.

## Adjustment

The adjustment of the RDS decoder is limited to the demodulator board. Tune to a station that transmits RDS, and adjust P1 until the opamp, IC1, supplies a signal with

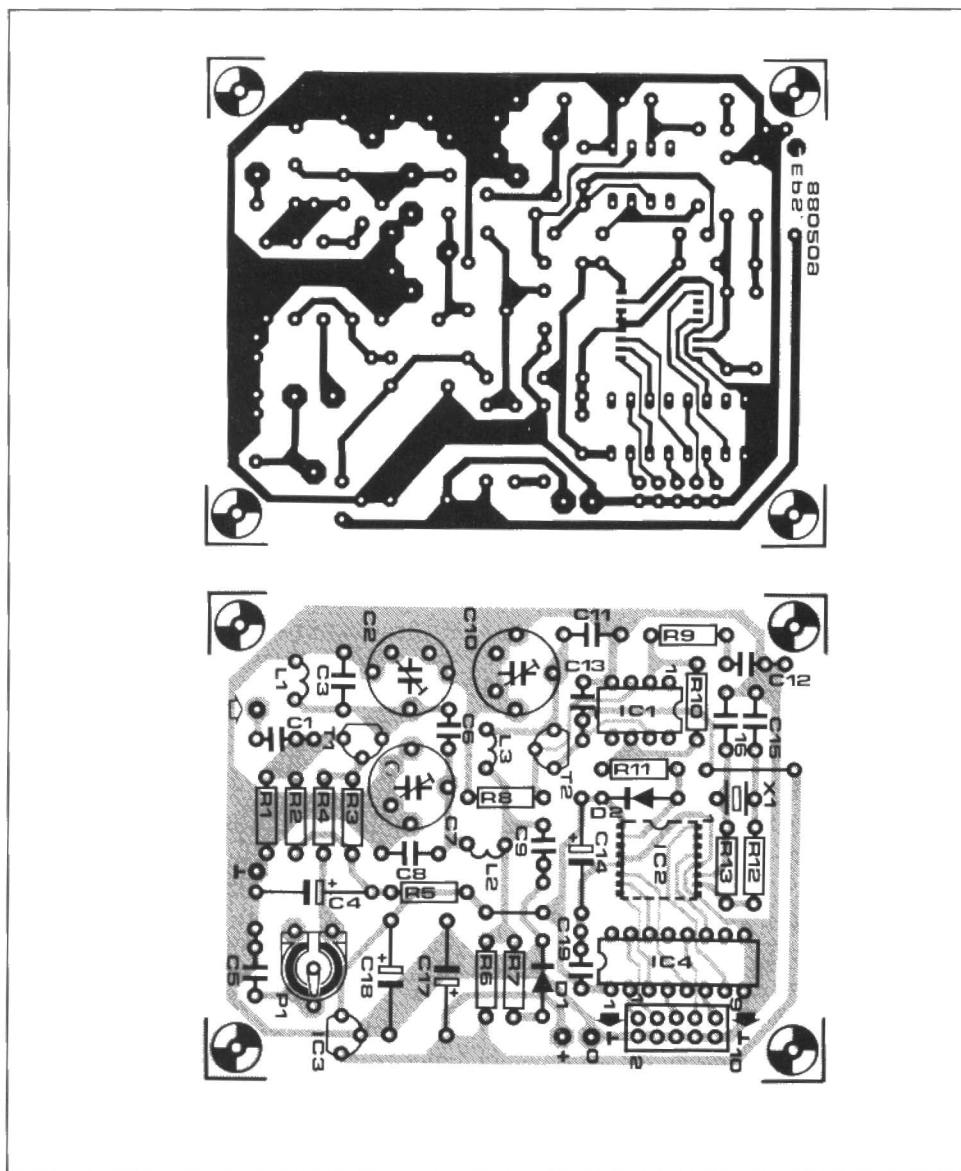


Fig. 8. Track layout and component mounting plan of the demodulator board.

## COMPONENTS LIST

### RDS DEMODULATOR BOARD

#### Resistors:

2	220kΩ	R1;R13
2	100kΩ	R2;R10
1	6kΩ	R3
2	4kΩ	R4;R8
1	1kΩ	R5;R9
4	2kΩ	R6;R7;R11;R12
1	100kΩ preset H	P1

#### Capacitors:

2	10nF	C1;C12
3	45pF trimmer	C2;C7;C10
3	47pF polystyrene	C3;C8;C11
1	47μF 16V	C4
3	100nF	C5;C13;C19
1	2pF	C6
1	4nF	C9
3	1μF 16V	C14;C17;C18
1	100pF polystyrene	C15
1	18pF polystyrene	C16

#### Inductors:

3	68mH (Toko 181LY-683)	L1;L2;L3
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#### Semiconductors:

2	1N4148	D1;D2
1	BF451	T1
1	BF494	T2
1	LF357	IC1
1	SAF7579T	IC2
1	78L05	IC3
1	4050	IC4

#### Miscellaneous:

1	4.332 MHz quartz crystal (20pF parallel resonance)	X1
1	printed-circuit board	880209

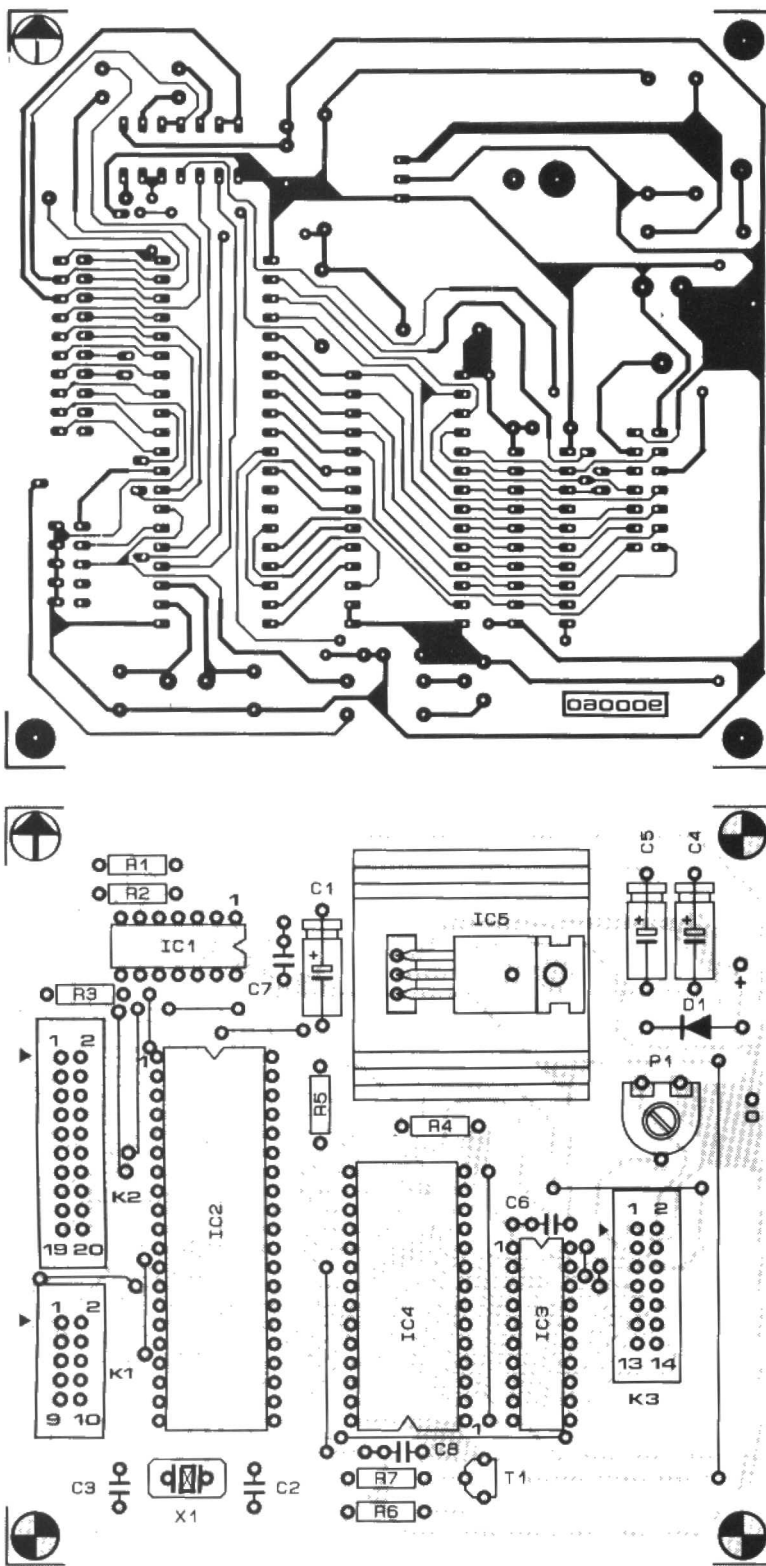


Fig. 9. Track layout and component mounting plan of the processor board.

an amplitude of 10 V<sub>pp</sub>. Next, peak the three trimmers on the demodulator board for the highest possible amplitude of the signal measured at the emitter of T2. Do not connect the demodulator and the controls cable to the decoder board as yet.

Connect a small loudspeaker to pins 16 and 2 of connector K2 of the completed decoder board. Power up the decoder board. The loudspeaker should produce a short series of notes. If not, the decoder does not work, and you are faced with a construction error that

must be traced and eliminated before proceeding.

Connect the cables for the display and the controls to the SBC, and set P1 to the centre of its travel. The 470 Ω resistor between pin 3 of K2 and ground pulls the P1.1 line of the 80C32 low, and causes the microcontroller to enter the RDS decoder program instead of the 'music generator' program. After applying power, all pixels on the top line of the LCD are black. Slowly turn P1 clockwise, and press the reset key, until you see the 'OK' in-

## COMPONENTS LIST

### RDS DECODER BOARD

#### Resistors:

4	100Ω	R1;R2;R3;R5
2	10kΩ	R4;R7
1	180Ω	R6
1	470Ω	R8
1	10kΩ preset H	P1

#### Capacitors:

3	10μF 25V axial	C1;C4;C5
2	22pF	C2;C3
3	100nF	C6;C7;C8

#### Semiconductors:

1	1N4001	D1
1	LED	D2
1	BC557B	T1
1	74HCT00	IC1
1	80C32	IC2
1	74HCT573	IC3
1	27C64 (ESS5951)	IC4
1	7805	IC5

#### Miscellaneous:

1	10MHz quartz crystal	X1
1	miniature SPDT switch with centre-off position	S1
2	miniature push-button	S2;S3
1	10-way PCB box header	K1
1	20-way PCB box header	K2
1	14-way PCB box header	K3
1	heat-sink for IC5	
1	printed-circuit board	900060
1	LCD display. The following types are suitable:	
	H2570 (1 × 16) Hitachi	
	LM016L (2 × 16) Hitachi	
	LM018L (2 × 40) Hitachi	
	LM038L (1 × 20) Hitachi	
	H2572 (1 × 40) Hitachi	
	LM16152A (1 × 16) Sharp	
	VK2116L Vikay	

dication.

Switch off the decoder board, and connect it to the demodulator via a 10-way flat-cable with IDC sockets at both ends. Connect the input of the demodulator to a suitable point in the FM tuner. Apply power to the demodulator and the decoder. The 'OK' message should appear briefly before the display shows the RDS information. The QUAL LED goes out when the reception quality is adequate.

#### References:

1. "Radio data system (RDS) demodulator", *Elektor Electronics* May 1989.
2. "Specifications of the radio data system RDS for VHF/FM sound broadcasting", EBU Tech. 3244-E. Supplements: 1, 2, 3, 4. \*

\* to obtain copies of these documents, use the order form in the EBU Catalogue of Publications, available from the documentation department of the **European Broadcasting Union • Ancienne Route 17A • Case Postale 67 • CH-1218 Grand Saconnex (GE) • SWITZERLAND.**

## LETTERS

Dear Sir—I have noticed that most photocopiers produce a blacker image on paper than on acetate film (even the proper stuff). It occurred to me that if a black enough image could be photocopied on to thin paper, e.g., 60 g/m<sup>2</sup> computer listing paper, and the paper then transparentized with suitable purpose-designed spray (ISO-draft) or anything that will make the paper see-through, an adequate positive image could be obtained. I found that spray silicon grease/lubricant worked really well. The use of thin paper helps to overcome the parallax errors mentioned in the recent article ("Make your own PCBs" *Elektor Electronics*, Sept. 1990, p. 30). A bit of experimentation with times is needed, but as an example, a PCB for the "Feedback killer" (*Elektor Electronics*, Febr. 1990) was produced first time without a single bad track. I claim no originality for this method: something similar was published in the May 1986 issue of *Elektor Electronics*.  
Gareth Evans, South Croydon.

Dear Sir—I'm considering installing a satellite system in my home, but wish to install the receiver in the loft to keep cable losses down, avoid visible thick black cables everywhere and make it easier to distribute the signal to all TVs in the house. That isn't a problem in itself, but does mean forgoing stereo sound, as the remodulated signal provided will only have the usual mono FM sound carrier. Since there is now a terrestrial stereo sound transmission standard, the logical solution would be to add a NICAM sub-carrier to the remodulated signal, so that NICAM-equipped VCRs can record it and viewers can revel in Dolby Surround-encoded films.

There aren't any encoding chips that I'm aware of and trying to achieve the same end with discrete logic would give the most talented digital design engineer nightmares. But some digital signal processors are well suited to the job. Analog Devices have been making a fuss about a recent addition, the ADSP-2105, claiming it is similar in price to the more sophisticated microcontrollers. A quick perusal of the data and a few quick calculations show that it could manage the task using less than half its throughput. Since I'm a software engineer, writing the DSP codes poses no problems. However, I have absolutely no idea when it comes to RF electronics and I doubt that reading *The Art of Electronics* will solve that!

If you decide the project is not suitable for publication, perhaps one (or more) of your readers would be interested enough to help with the RF and A-D work.  
Paul Chambers, Reading

*We are interested in such a project, but, owing to the many other commitments of our design laboratory, cannot start it till well into the second half of this year. Interested readers, please write.* [Ed]

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**BARGAIN.** 1500 electrolytics; 1500 non-electrolytics; 300 assorted components. Only £20.00 plus £2.50 p&p. Mr. A. Khan, 349 St. Helens Road, Bolton BL3 3QD.

**WANTED.** Astec 2310 satellite television receiver modules. Phone Roger on (0928) 712 224 (Answerphone).

**WANTED.** Manual or circuit diagram for Telequipment DM64 oscilloscope. Phone R. Bedford on (0244) 660341.

**FOR SALE.** Crimson pre- and power-ampli-

fiers, 100 W, mono blocks AR77, turntable Sansui cassette deck. Phone T. Fisher on (0703) 474 396.

**WANTED.** ZNA234, UAA3000 IC. Would also like pen friendship on electronics. Masood Nazarzadh, P O Box 51335 - 4575, Tabriz, Iran.

**SIEMENS** 20 MHz luggable process programming panel & 100U industrial controller, £1800. Phone J. Budden on (093 586) 2433.

**FOR SALE.** Surplus electronic components. Send sae for list to Alan Auden, 206 Ellerdine Road, Hounslow, TW3 2PX.

**FOR SALE.** Audio amplifiers, turntables, all hand built and hard wired with silver PTF wire, SMD components, MOSFETs. Mr. J.D. Reece, 12 Railway Cottages, Station Road, Whitstable, Kent CT5 1JZ.

**HELP.** Any data on Philips MAB 8461 PW 135/187  $\mu$ computer chips. Write to Phil Collins, 177 Cathedral Road, Pontcanna, Cardiff CF1 9PL.

**FOR SALE.** Basic *Elektor Electronics* computer Meek-it complete kit as received. Offers. Call Gordon on 081 303 0396.

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